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NRE Staff Report

A STOCHASTIC SIMULATION OF THE ECONOMIC EFFECTS OF THE SPREAD OF THE GYPSY MOTH THROUGHOUT THE UNITED STATES

Program Documentation & Users Guide
For
GYMMSIM1

by

Henry S. Foster, Jr.

July 1982

ERS Staff Report No. AGES820701

Natural Resource Economics Division
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ABSTRACT

A computerized model for estimating the economic effects of the spread of the gypsy moth throughout the United States has been developed. The model, GYMMSIM1, uses stochastic simulation in a financial budgeting framework over a planning horizon and has been developed to allow a wide range of assumptions and policy alternatives to be simulated. This manuscript provides general model documentation describing the use of program parameters for various scenarios, definitions of variables, a description of the SAS data base required for the simulation, and SAS macros used. Technical appendices provide information for those who wish to modify, revise, or improve the program.

Key words: Gypsy moth, stochastic simulation, financial budgeting, planning horizon, present value, documentation.

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This paper was prepared for limited distribution to the research community outside the U.S. Department of Agriculture.

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INTRODUCTION

The gypsy moth (GM) is a pest which has received increasing attention in the past few years. From its origin in Massachusetts in 1869, it has now spread throughout New England and the Middle Atlantic States. It is a nuisance to residential households, and governmental officials expect an increasingly strong public outcry for control or eradication of the pest as it spreads to more populated areas. However, the pest has not proven to be amenable to accepted pest management practices. Further complicating the situation is the fact that GM is spread artifically through commercial and other activities such as: vacationers driving campers from one area of the country to another; the movement of nursery (forestry) products; and the movement of household goods which might contain egg masses of the pest. The spread of GM through these type activities is stochastic (random) in nature and could result in GM being "imported" to any region of the country, at any time.

It is now recognized that GM cannot be eradicated from infested parts of the Northeast, but hopefully its spread can be controlled. Several alternative policies have been proposed to minimize the economic impact of the spread of GM. The evaluation of these policy alternatives in terms of total costs and benefits was the motivating factor for the development of GYMMSIM1, the Gypsy Moth Movement Simulator, version #1.

GYMMSIM1 is a stochastic computer simulation for modeling the economic effects of the spread of GM. It is written in modular, structured form using Statistical Analysis System (SAS) as the programming language. This allows modification to subportions of the program with relative ease, especially for those portions which may require extensive modification as more knowledge of the gypsy moth's life cycle becomes available. Thus, GYMMSIM1 represents only the first version of a model which may be further altered in the future.

This documentation presents the computer model as presently structured. It explains the rationale for the model specification and the simplifying assumptions that resulted from time and budget constraints as well as limited knowledge of the dynamics involved in the spread of the GM only when such information explicitly affects the computer modeling effort. Finally, this document assumes that the reader is familiar with SAS.

BACKGROUND

The GM was imported into the U.S. in 1869 for use in biological experimentation. Unfortunately, the pest escaped from its cages in Medford, Massachusetts and has been spreading throughout the northeastern part of the U.S. The overall northeastern area now occupied by the GM is known as the generally infested area (GIA). The boundary between the GIA and the remainder of the U.S. to the west and south is known as the leading edge (LE).

At one time an attempt was made to contain the GM to the New England area. For many years the Hudson River area served as a natural barrier in this regard. However, a hurricane provided the necessary impetus to breach this barrier. The GM then spread throughout the Mid-Atlantic States and has at this time reached Virginia.

As the GIA has expanded over the years, some areas have become severely infested by the GM, and large scale defoliation of trees has occurred. For the most part these regions have not been important for commercial forestry production. However, the pest has been a great nuisance to humans, due both to the destruction of the aesthetic qualities of residential properties and scenic public areas and also to the unpleasantness of large numbers of GM, much as flies are unpleasant at a picnic. The pests are noisy, destroy plantlife, and are repugnant, especially when large numbers are present. Consequently, communities experiencing these outbreaks have been demanding action by public officials.

An additional factor encouraging the spread of the GM is human activity. We are very mobile creatures and provide the GM many potential opportunities to spread. Vacationers from all across the country move in and out of the GIA. Nurseries within the GIA ship products out of the GIA. People move from within the GIA to regions outside of the GIA. In each of these examples, clusters of GM egg masses may be transported to remote areas within hours or days-- something which might not occur naturally for hundreds of years. As the size of the GIA has increased, the opportunity for spreading the GM by these "artificial" means has also increased. Thus, we should expect the GM to spread more quickly and to many more areas, some far removed from the present GIA.

Since the GM poses problems as a nuisance, hampering recreational activities and causing losses to recreational and related industries, residential and business entities will expend resources in an effort to control and minimize its disruptive effects. Also, expenditures may be necessary to remove and/or replace trees and plants killed by the GM. Moreover, uncertain economic impacts loom in the future as the GM moves into areas important for lumber and other forestry products. In the long run GM could possibly be an important factor affecting the ecology of important lumber producing regions of the country.

Although several governmental agencies are involved, the Animal and Plant Health Inspection Service (APHIS) is the primary government agency concerned with the gypsy moth problem and has established inspection programs to prevent the movement of infested articles of commerce out of the GIA as well as other programs to regulate, detect, and eradicate infestations which occur outside of the GIA. Thus, APHIS recognizes these potential problems, including the fact that the total area affected by the GM is increasing rapidly due both to the increasing spread by artificial means and to the geometric shape of the GIA. They are also aware that political pressure for control of the GM is likely to increase as more communities become affected. At the same time, funds for combating the problem are limited. As the GM spreads, any given funding level will be used to combat the GM over a larger area, diluting the resoures available at any one location. The problem is further aggravated by reductions in current funding levels. Thus, if we are to stand any chance of controlling the

spread of GM, we must use the most efficient program possible. APHIS must decide whether it is beneficial to conduct any program to combat the GM and if so, which program would be most effective.

In this regard, many alternative programs are possible. They include: (1) having no APHIS program, (2) having only the APHIS inspection program within the GIA, (3) continuing only the present APHIS eradication program for isolated infestations outside of the GIA, and (4) continuing both the inspection and eradication programs as presently implemented.

The objective of the GYMMSIM1 computer model is to analyze these and other possible program options under various scenerios to determine the resultant total costs and benefits.

The following section provides a general description of the model including rationale for the various parameters required for any given program option and scenario. A detailed list of variables and definitions then follows. (A detailed flow chart of the model is provided by Appendix C).

GENERAL MODEL DESCRIPTION

The following narrative describes several general scenarios and how the computer models these scenarios. Parameters which must be specified are listed in parentheses (all capital letters) in that part of the narrative which first describes their function. Finally, a discussion of other parameters relating to the APHIS program and a discussion of modeling the movement of the LE of the GIA is presented.

One computer run can give multiple simulations (NS). The present value of each decade within the planning horizon of each simulation is listed separately. Thus, a distribution may be derived if desired.

Base Scenario

If no action is taken by APHIS, the LE of the GIA will move south and west year by year at a "natural" rate. This natural movement, which ocurs without any government program, forms the "base scenerio" against which other programs are measured. There is no measurement of losses behind the LE since no action will be taken in this area under any circumstances. The present value of losses occurring in front of the LE provides the criteria against which other programs are evaluated. The present value, of course, varies with the discount rate (R) used for the simulation.

Retarding Movement of the Leading Edge

If action is taken to retard the movement of the LE, the GIA will grow at a slower rate than otherwise, and losses outside the initial position of the LE will be delayed or prevented, depending on the rate of movement of the LE. There is a certain program cost associated with the prevention program each year as well as losses which do not occur each year because of the program but would have occured under the base scenario. These

costs and prevented losses can be tabulated over the planning horizon (YRS) of the simulation, and their present value calculated. The total cost of retarding the movement of the LE (COSTNAT) the initial year of the simulation, is entered. This cost, over time, is a linear function of the total length of the LE.

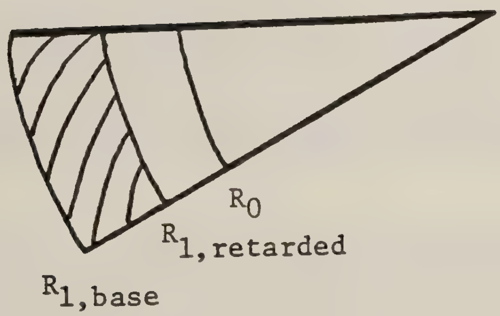
The losses prevented by a program designed to retard the movement of the leading edge include those losses which do not occur in the area between the position of the LE and the corresponding position of the LE in the base scenerio. In Figure 1, the initial area of the general infested area spreading southward and westward is represented by that portion of the sector from the center to the radius R_o. Under the base scenario, the GIA would expand at a rate (V0) and the LE advances to radius $R_{1,base}$ at the end of the first year. However, a program designed to slow the spread of the GIA limits the advancement of the LE to $R_{1,retarded}$, at a rate (V00) equal to or less than (V0). The area between these two radii, represented by the hatched areas in Figure 1, represents the area that would have been absorbed into the GIA under the base scenario, but which has been prevented from occuring by a program to slow the movement of the LE. The area in which these losses are prevented is assigned a constant loss factor (contained in ADJF) for each of the timber, recreation, and residential categories multiplied by the proportion of the total area receiving the timber, recreation, and/or residential loss (ADJEFF (2, 1,), ADJEFF (2, 2), and ADJEFF (2, 3), respectively). Since the objective function is measured in terms of the value of costs and losses, these prevented losses enter the objective function as a negative number.

Untreated Isolated Infestations

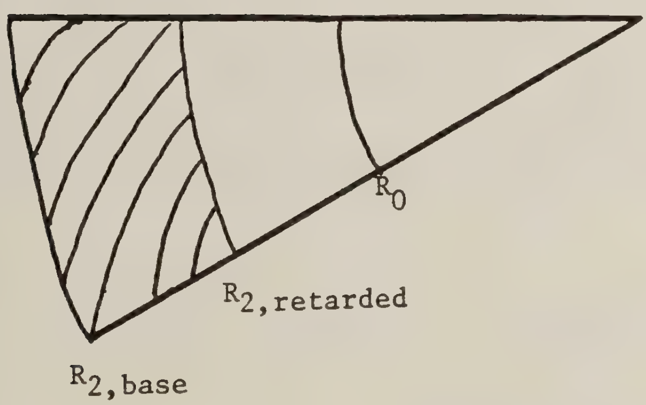
The artificial spread of the GM may also be modeled. This spread is clearly stochastic in nature. A camper, a shipment of Christmas trees, or a shipment of household goods containing a cluster of GM eggs are examples of activities which could lead to an isolated infestation being spread to any part of the country, inside or outside the GIA. The various categories of activities could be modeled separately, but, lacking essential parameter values for these activities, we assume that the probability of any city (SMSA or standard metropolitan statistical area) receiving an isolated infestation is directly related to the population of the SMSA (a proxy for the amount of commercial activity occurring) and inversely related to the distance of the SMSA from the LE (the further away from the LE, the less commercial activity associated with cities within the GIA). Given the number of isolated infestations occurring each year of the planning horizon (NI), a random number generation with a given seed (SEED) can then choose the SMSA's which receive an isolated infestation(s) during the year. (The SMSA is actually only a proxy for the general overall geographical area surrounding the city. However since most of the population within the general area is near or within the SMSA, it should be a good proxy.)

Assuming an initial size for an isolated infestion (AREA0) and a yearly growth rate (GR) for the area covered by an isolated infestation, we may calculate the area covered by the isolated infestation year by year until the SMSA is absorbed into the GIA or until the end of the planning horizon. (When the isolated infestation is absorbed into the GIA, it no longer

Figure 1. MOVEMENT OF THE LEADING EDGE--BASE SCENARIO VERSUS A PROGRAM TO RETARD THE MOVEMENT OF THE LEADING EDGE.



A. Position after one year.



B. Position after two years.

causes additional losses above those occurring in the base scenerio). Over the planning horizon a city may receive many isolated infestations. There is some probability that a new isolated infestation may occur in a specific area within a SMSA which is already covered by a previous isolated infestation. This is particularly true after a number of isolated infestations within a given SMSA have grown for a number of years. The model does not attempt to model this phenomenon stochastically, but assumes that all isolated infestations up to a specified number (NINFMAX) are separate and independant. All isolated infestations above this number are assumed to occur in an area already infested and thus do not add to the total infested area.

The model has taken a given isolated infestation, randomly assigned it to a SMSA, and allowed the area covered by the isolated infestation to grow over time. Associated with this area is a loss function to determine the losses caused by the particular isolated infestation over the various years it is in effect.

Each SMSA could have a different amount of loss from lumber, recreational, and residential categories. The computer model provides this option by allowing the programmer to specify individual loss values for each city by category of loss (see the section on SAS Data Base). The computer program allows assigned loss values to be "blown up" or scaled by a constant factor (ADJF). (This feature is particularly useful if all cities have the same loss for any given category. That category can be represented by a 0-1 dummy variable and multiplied by the scale factor to derive the actual loss value. Recognizing that only a portion of any isolated, infested area will suffer losses, the program has an effective loss factor (ADJEFF (1, 1), ADJEFF (1, 2), and ADJEFF (1, 3) for timber, recreational, and residential losses) to calculate that proportion of the area to be assigned an economic loss. In addition, the program recognizes that residential density is not constant throughout a SMSA and the surrounding area. This is accounted for by keeping a yearly running total of an SMSA's total infested area. The sum of all infested areas up to a given stated proportion (PART) of a SMSA's total area are assumed to receive the total residential loss function. Any infested area above the stated proportion is assigned only a fraction (FRACT) of the original residential loss function. Finally, an isolated infestation does not immediately cause damages even though it occupies an area. An incubation period of several years (SKIP) is required for the pest to develop to the point of causing severe defoliation and accompanying economic losses. After this period, the model assumes the pest causes economic losses.

Eradicated Isolated Infestations

When a city receives an isolated infestation that is not treated, the growth process described in the previous section occurs. However, the model provides for the eradication of the infestation with 100 percent effectiveness at a specified cost per infestation eradicated (ERADCOST). In this case the isolated infestations do not grow and cause losses.

However, there are several situations in which an isolated infestation would not be eradicated even though an eradication program is in effect. This includes cities in which the environment is deemed too severe for the

GM to survive and thrive (all categories of the SMSA's loss functions in the SAS data base are zero) as well as those cities so close to the LE (less than BORDER) that the city will be absorbed into the GIA within a relatively short period of time.

APHIS Program Parameters

Several parameters which relate to the APHIS program must be specified. As previously described, the first year total cost (COSTNAT) of retarding the movement of the LE must be entered. Costs in subsequent years are a linear function of the length of the LE. If there is no program to retard the LE, COSTNAT = 0. The initial total cost of the APHIS regulation and detection program (FC) must be entered as well as the average cost per square mile (VC) of this program . Total costs in subsequent years are then calculated as a linear function of the total area within the GIA. Finally, as previously, described, the cost of eradicating an isolated infestation (ERADCOST) must be entered.

The number of isolated infestations each year (NI) has been entered to reflect expert opinion. This could later be modified to reflect some as yet unspecified functional relationship. In addition, APHIS could undertake a program to prevent some percentage (REGEFF) of potential isolated infestations from actually occurring. The computer model allows for this by multiplying the yearly number of new isolated infestations (NI) by the percentage of potential isolated infestations actually occurring (1-REGEFF) and rounding off the answer.

Modeling the Leading Edge

Although the GIA is actually irregularly shaped, that portion of the GIA facing and expanding south and west is basically shaped as a sector of a circle (see Figure 1). Thus, for modeling purposes, the LE is the perimeter "F" of a sector of a circle whose radius increases each year as the natural spread of the GM expands the GIA. Several model parameters are dual valued so that, if desired, future versions of the model may have two different sectors of two different concentric circles to represent the GIA. In this manner different parts of the GIA would be allowed to expand at different rates.

Data Requirements

The model requires a data base containing information about the SMSA's outside of the GIA. It also requires a matrix giving the probabilities of any given city receiving an isolated infestation in any given year. Finally, the model requires that the various parameters as described previously, be specified. These parameters are contained at the beginning of the program in a macro named PERIMETE. Several of these parameters are multivalued; thus, matrix dimensions are included in the following definitions.

VARIABLES

The following variables are contained in macro PARAMETE. This macro occurs within the SAS PROC MATRIX procedure, and all variables must be input in proper matrix form. Dimensions are noted in subscripts in the following descriptions:

R_{1x1} = the discount rate (yearly rate of interest), expressed as a decimal.

NS_{1x1} = the number of simulations to make in the computer run. (Each simulation starts at the initial position of the leading edge and progresses to the end of the planning horizon.)

YRS_{1x1} = the number of years (planning horizon) contained in each simulation.

$SEED_{1x1}$ = 7 digit odd integer to control the start of the random number generator.

GR_{2x1} = the yearly growth rate of the area of an isolated infestation expressed as a decimal. Two different growth rates are allowed.

$AREA0_{1x1}$ = the assumed initial area (in acres) of a new isolated infestation.

$NINFMAX_{1x1}$ = the number of independent isolated infestations a given city may receive. Any isolated infestation above this number is implicitly assumed to be within an area of the SMSA previously infested. Thus, this new infestation does not increase the total area of isolated infestations within the SMSA.

$PART_{1x1}$ = that proportion of the area of a SMSA which receives the full value of the residential loss function. When the total area of the various isolated infestations within a given SMSA exceeds this proportion of the SMSA's total area, this "excess" portion of the infested area receives only a fraction of the original residential loss function.

$FRACT_{1x1}$ = that fraction of the residential loss function assigned to that part of the infested area above a given proportion of the SMSA's total area (See PART, above).

$COSTNAT_{1x1}$ = the APHIS cost of limiting the yearly movement of the leading edge at the beginning of the planning horizon. (See section on the appropriate COST macro for specific data to include in COSTNAT).

FC_{1x1} = the initial cost of the APHIS inspection program at the beginning of the planning horizon. (See section on the appropriate COST macro for specific data to include in FC).

VC_{1x1} = additional APHIS costs which change over time. (See section on the appropriate COST macro for specific data to include in VC).

$ERADCOST_{1x1}$ = the cost of eradicating each isolated infestation.

BORDER_{1x1} = the distance beyond the LE of the GIA within which no eradication program will take place even though an isolated infestation occurs.

WIDTH_{2x1} = width (in degrees) of the sector within each of the two concentric circles used in the model to represent the expanding portion of the GIA.

SKIP_{1x1} = the number of years from the beginning of an isolated infestation through the last year within which no monetary loss is precieved. In other words, the "build up" period of the GM infestation before it causes damages.

ADJ_{2x3} = multiplicative adjustment factor for (1) lumber, (2) recreational, and (3) residential losses. The data base required by the program contains a loss factor for each of these categories for each SMSA. Row 1 of this variable allows these loss factors to be scaled for calculating losses from an isolated infestation. Row 2 allows different scaling factors to be used in calculating "losses prevented" by a policy which retards movement of the leading edge (see figure 1).

ADJEFF_{2x3} = adjustment factor giving that proportion of an infested area actually receiving economic losses for (1) lumber, (2) recreational, and (3) residential losses. Row 1 gives the proportions for an isolated infestation within an SMSA while row 2 gives the proportions for the total area which has been prevented from being absorbed into the GIA by a program to retard the movement of the leading edge.

NI_{1xYRS} = the number of isolated infestations assumed to occur each year of the planning horizon.

VO_{1x1} = rate of movement of LE in base run (miles per year).

VOO_{1x1} = rate of movement of LE in this scenerio (miles per year).

Macro PARAMETE also contains variables ISOGROW, KOST, and YRDATA. These variables allow the selection of different ISOGROW, KOST, and YRDATA macros (through the use of IF statements) depending on modeling considerations. At this stage of model development, there are no alternative macros for ISOGROW, KOST, and YRDATA; thus, these variables should all be assigned a value of 1.

SAS DATA BASE

The final item which may be varied for policy analysis is the SAS data base being used for the analysis. This data base has been processed by a previous SAS program which takes the original data for each SMSA outside of the GIA at the start of the simulation, processes it, and outputs it to a SAS data base in a form needed by GYMMSYM1. The data base is composed of three SAS data sets, each of which is needed by GYMMSYM1. Each of the data sets has a first level name which is the same as the DD-name of the DD statement giving the operating system (OS) data set name which contains

the SAS data base. The following sections, headed by the SAS data set second level name, describe the information contained in each SAS data set.

INFO. This data set contains information about each SMSA. It has been sorted by state and SMSA (city), and contains the following variables:

CITY - an alphanumeric variable containing the name of the SMSA

STATE - an alphanumeric variable containing the post office abbreviation of the name of the state.

POP78 - SMSA populations (in 1978).

DIST - the distance, in miles, from the SMSA to University Park, Pa., the center of the concentric circles used in the model to represent that portion of the GIA which moves south and west.

DUMMY - a dummy variable with one of the following values:

0 - the environment of the region surrounding the SMSA is such that the isolated infestation is not likely to survive and/or grow.

1 - the isolated infestation will grow at a slow rate (value contained in GR(1, 1)).

2 - the isolated infestation will grow at a fast rate (value contained in GR(2, 1)).

LUMLOSS - the average dollar loss (per square mile) of timber caused by a GM infestation in the general region of this SMSA. (If the loss is an amount which remains constant (or zero) over all SMSA's, this value can be 1 and then multiplied by ADJF.)

RECLOSS - the average dollar loss (per square mile) of recreational output in the general region of this SMSA. (Also 1, if uniform losses are assumed.)

RESLOSS - the average dollar loss or cost (per household) of residents in the SMSA (Also may be 1. However, this would be a poor assumption for this variable due to the different populations, and demographic characteristics among the SMSA's.)

CITYAREA - the area of each SMSA, expressed in square miles.

VR - determines which concentric sector the SMSA is in, the sector within which the LE is progressing at a slow or fast rate, as given in V_{2x1}, the rate of movement of the LE.

PROB. This SAS data set contains a matrix which gives information on the probability of any city (SMSA) receiving a given isolated infestation. It is in the form of a cumulative distribution function (CDF) for each year since these probabilities, as presently specified, are in part a function

of the distance of the SMSA from the LE and thus, vary over time. Therefore, this data set is in the form of a matrix in which the rows are the cumulative probability of any city receiving a random infestation in a given year while the columns represent these probabilities for the various years.

PARA1. The probability of any city receiving an isolated infestation is a function of:

$EDGEO_{2x1}$ = the distance (miles) of the LE from the center of the concentric circles (University Park) at the start of the simulation.

V_{2x1} = the rate of movement (miles per year) of the LE as the GIA expands.

KR = the threshold distance from the LE beyond which the probability of any SMSA receiving an isolated infestation decreases with distance. (At any distance less than KR, the probability of a SMSA receiving an isolated infestation does not vary with distance and is the same as it would be at KR.)

YRS1 = the number of years for which the CDF's have been calculated.

Since the probabilities in the cumulative distribution functions depend on the values of the variables EDGEO, V, KR, and YRS1, these variables are stored in a SAS data set and have been concatenated into a 6x1 array named PARA. This prevents a programmer from inadvertently changing the value(s) of any of these variable(s) within the program and thus, running the program with an incorrect CDF. If the rate of movement of the leading edge selected for the simulation (VOO) is not equal to V, the rate of movement of the leading edge used to generate the CDF, a warning message is written, and the simulation portion of the program terminates.

MACROS

Several portions of GYMMSYM1 are contained in SAS macros. This makes it possible to have several versions of these portions of the program and choose among the alternatives through the use of IF statements associated with the variables ISOGROW, KOST, and YRDATA as explained in the section on variables.

PARAMETE. The beginning of this macro contains NOTE statements which start the output section of the computer printout. These notes describe the scenerio being run and should be updated to reflect the new scenerio when any parameter is changed. The remainder of PARAMETE contains parameters which may change from simulation to simulation. These parameters have been defined in the section on variables, and unlike the separate data input section used in a compiled Fortran program, all parameters in this SAS simulation program are entered in macro PARAMETE (the first section of the SAS program) using SAS assignment statements in proper matrix notation.

KOST1. This macro calculates the yearly costs of all APHIS programs (excluding eradication) for the planning horizon. These costs are contained in variables FC, COSTNAT, and VC and as modeled in KOST1 represent costs which are fixed, are a linear function of the length of the LE, and are a linear function of the area absorbed into the GIA after the start of the simulation, i.e. the total area of the GIA at year J minus the initial area of the GIA at year zero. For example, these costs, as modeled in KOST1, consist of two possible components: the inspection program and the program to slow the expansion of the LE. The cost of the inspection programs is a function of the area within the GIA. The yearly cost of inspecting the area (at time = 0) within the GIA is included in variable FC while the cost of inspecting an additional square mile is contained in VC. The cost of slowing the natural spread of GM is a linear function of the length of the LE. The initial cost of this retardation program for the initial length of the LE is contained in COSTNAT.

ISOGROW1. This macro takes the assumed size of an initial infestation (in acres), converts it to square miles, and calculates the size of an isolated infestation starting at year 1 and continuing throughout the planning horizon. This is done for each of the two growth rates given in GR. The resulting areas are stored in $AREA_{2xYRS}$.

YRDATA1. This macro forms the heart of the simulation and is the most complex portion of the program. If ERADCOST, the cost of eradicating an isolated infestation, is any amount other than zero, the macro checks to see if the infestation is the required minimum distance from the LE, and is in an SMSA which will suffer economic loss, and if so, increments the eradication costs and APHIS eradication program counter for that year.

If ERADCOST is zero, the macro checks to see that the city in question has not exceeded its maximum number of independent, isolated infestations. If not, it calculates the number of years until the LE of the GIA will reach the city. Then, if the SMSA will suffer economic losses, the macro uses the appropriate area of an isolated infestation over the time frame, and calculates the losses from timber, recreational, and residential sources, after the end of the "incubation" period of the infestation and throughout the years the isolated infestation is a factor in causing economic losses. These losses are accumulated for all cities for each year in the planning horizon.

SUMMARY

This documentation has presented a brief background of the spread of the GM and a general model description that includes examples of scenerios which may be simulated by the model. These scenerios show how the parameters are used in the model. A formal definition of the variables, a description of the macros used in the program, and a description of the SAS data base required by the model then follows.

These sections provide the essential information needed to use the computer program to simulate different policy alternatives. Additional information needed to run the program at Washington Computer Center is contained in Appendix A, which lists the job control cards needed for the IBM system. Appendix B contains a description of the program output along with a sample output.

Appendices C and D provide more technical information on the program, oriented toward programmers and model builders who may wish to modify the model. Appendix C provides a description of the program with accompanying flow charts. Finally, Appendix D provides a source program listing corresponding to the sample output in Appendix B. The listing includes many comments which will also be helpful to those interested in the more technical aspects of the model.

APPENDIX A

JCL CONSIDERATIONS

JCL CONSIDERATIONS

GYMMSIM1 is programmed in SAS, version 79.5 and has been run on the IBM computer system at the U.S.D.A. Washington Computer Center (WCC). The complete program needed to run the model at WCC is shown below:

A. Control cards:

   1. Job Card

   2. //SAS EXEC SAS,PARM='S=0',Region=340K

   3. //APHIS2 DD DISP=SHR,DSN=ERS23.ER6HF.SASDS.AHPHIS2.DATA

   4. //*APHIS2 EDGEO=172,V=10,KR=100,YRS=30

   5. //APHIS3 DD DISP=SHR,DSN=ERS23.ER6HF.SASDS.APHIS3.DATA

   6. //*APHIS3 EDGEO=172,V=2,KR=100,YRS=30

   7. //SAS.SYSIN DD *

B. SAS Source Program (contained in Appendix D).

The "//SAS" card in the control section tells the computer to use SAS, version 79.5. Only the "//APHIS2" or "//APHIS3" card is needed for any given simulation run. APHIS2 and APHIS3 are the DD name which correspond to the first level names of the three SAS data sets used in the program. The "//*" cards are comment cards which give the DD name and parameter values applicable to each data set. For example, the OS data set named ERS23.ER6HF.SASDS. APHIS2.DATA was derived and based on the parameters: EDGEO=172 miles, V=10 miles/year, KR=100 miles and YRS=30 years. (Although these two listed SAS data bases are the only SAS data bases at the present time, others may be added at a later date.) The "//SAS.SYSIN DD *" card tells the computer that the SAS source program immediately follows this card.

The CPU time needed to execute a program varies considerably, depending on parameters. For NS = 1, a planning horizon of 30 years, and total number of new isolated infestations not more than 2000, execution time has varied between 5 and 50 seconds. Scenerios which do not use an eradication program take the most time for execution due to the growth of the infestations over the various years and calculation of the loss functions year by year for each infestation.

APPENDIX B

OUTPUT DESCRIPTION

AND SAMPLE OUTPUT

GYMMSIM1 OUTPUT

The initial section of a simulation output provides a note describing the scenerio being simulated. This is followed by a listing of all parameter values (in SAS matrix notation) accompanied by a note describing the values being presented. Some summary statistics from program calculations are also presented in this section.

The second section provides summary statistics for the computer run and includes on a yearly basis: the total number of new isolated infestations, the grand total area of isolated infestations beyond the LE, the grand total area added to the GIA since the start of the simulation, value of timber, recreational, and resdential losses for that year, APHIS inspection costs, eradiction costs and total costs for the year, and sum total of losses due to the pest plus APHIS costs for that year. These statistics are average values per simulation. The third section provides information similiar to the second section. However, all dollar figures from the beginning of the simulation through the applicable year have been converted to a present value basis. The final output section lists alphabetically by state, all SMSA's in the data set. It also lists the average number of isolated infestations per simulation from the start of each simulation through the end of each decade, and also some of the more pertinant input data about each SMSA including population in 1978, distance of the SMSA from Harrisburg, Pennsylvania, loss factors for timber, recreation, and residential areas, and area of each SMSA (in square miles).

```
                  ********************
         HOUSEHOLD GOODS INSPECTION PROGRAM ONLY
           REGULATION EFFICIENCY = 100 PERCENT
            35 PERCENT OF CALL-IN'S INSPECTED
                    FC = $1,158,000
                  VC = $6.94 / SQ. MILE
       REGULATION EFFICIENCY (REGEFF) = 60 PERCENT


         DISCOUNT RATE (YEARLY RATE OF INTEREST)

           R                  COL1

           ROW1                0.1

           MACROS CHOOSEN FOR THIS COMPUTER RUN

           ISOGROW            COL1

           ROW1                  1


           KOST               COL1

           ROW1                  1


           YRDATA             COL1

           ROW1                  1

         NO. OF SIMULATIONS IN THIS COMPUTER RUN

           NS                 COL1

           ROW1                  1
```

YRS	COL1
ROW1	30

MAX NO. OF INDEPENDENT ISOLATED INFESTATIONS WITHIN A CITY   NO ISOLATED INFESTATION ABOVE THIS NO. INCREASE DAMAGED AREA

NINFMAX	COL1
ROW1	100

PROPORTION OF CITY'S AREA RECEIVING FULL RESIDENTIAL LOSS FUNCTION -- REMAINDER RECEIVES ONLY FRACTION OF FULL AMOUNT

PART	COL1
ROW1	0.5

PROPORTION OF RESIDENTIAL LOSS FUNCTION CHARGED TO CITY AFTER SPECIFIED PROPORTION OF CITY''S AREA AFFECTED

FRACT	COL1
ROW1	0.25

SCALE FACTOR FOR VALUES OF TIMBER, RECREATION & RESIDENTIAL LOSSES

ADJF	COL1	COL2	COL3
ROW1	3584	8.1	478
ROW2	3584	8.1	10682

PROPORTION OF SMSA & GIA SAVED SUBJECT TO LOSSES FROM LUM,REC,RES

ADJEFF	COL1	COL2	COL3
ROW1	0.025	0.025	0.025
ROW2	0.025	0.025	0.025

LOSS FACTOR (PER SQ MILE) FOR ISO INFES IN SMSA'S & SECTOR OF AREA KEPT OUT OF GIA

LF	COL1	COL2	COL3
RCW1	89.6	0.2025	11.95
RCW2	89.6	0.2025	267.05

KEY FOR START OF RANDOM NO. GENERATOR

SEED	COL1
ROW1	1111111

INITIAL "RADIUS" OF LEADING EDGE

EDGE0	COL1
ROW1	172
ROW2	172

NATURAL SPREAD RATE OF LEADING EDGE FOR SLOW & FAST AREAS (MILES/YEAR)

V	COL1
ROW1	10
ROW2	10

BASE RUN NATURAL SPREAD RATE OF LEADING EDGE

V0	COL1
ROW1	10
ROW2	10

MIN DISTANCE FROM LEADING EDGE BEFORE ERADICATION EFFORTS WILL TAKE PLACE

BORDER	COL1
ROW1	100

KR	COL1
ROW1	100

WIDTH OF "CORRIDOR" OF NAT SPREAD (SLOW & FAST) IN DEGREES

WIDTH	COL1
ROW1	103
ROW2	0

SLOW & FAST GROWTH RATES OF ISOLATED INFESTATIONS (1+GROWTH RATE)

GR	COL1
ROW1	1.25
ROW2	1.5

AREA OF ISOLATED INFESTATION WHEN INITIALLY FOUND (ACRES)

AREA0	COL1
ROW1	200

AREA OF ISOLATED INFESTATION OVER TIME GIVEN INITIAL SIZE OF AREA & IT'S GROWTH RATE (SQ. MI.)

AREA	COL1	COL2	COL3	COL4	COL5	COL6	COL7	COL8	COL9	COL10
	COL11	COL12	COL13	COL14	COL15	COL16	COL17	COL18	COL19	COL20
	COL21	COL22	COL23	COL24	COL25	COL26	COL27	COL28	COL29	COL30
ROW1	0.390625	0.488281	0.610352	0.762939	0.953674	1.19209	1.49012	1.86265	2.32831	2.91038
	3.63798	4.54747	5.68434	7.10543	8.88178	11.1022	13.8778	17.3472	21.684	27.1051
	33.8813	42.3516	52.9396	66.1744	82.7181	103.398	129.247	161.559	201.948	252.435
ROW2	0.46875	0.703125	1.05469	1.58203	2.37305	3.55957	5.33936	8.00903	12.0135	18.0203
	27.0305	40.5457	60.8186	91.2279	136.842	205.263	307.894	461.841	692.762	1039.14
	1558.71	2338.07	3507.11	5260.66	7890.99	11836.5	17754.7	26632.1	39948.1	59922.2

COST OF SLOWING DOWN NATURAL SPREAD RATE GIVEN INITIAL LENGTH OF LEADING EDGE

5

```
                     COSTNAT        COL1

                     ROW1              0

                    FIXED COST OF APHIS INSPECTION PROGRAM

                     FC             COL1

                     ROW1        1158000

                       VARIABLE COST OF APHIS PROGRAM

                     VC             COL1

                     ROW1           6.94

COST OF ERADICATION OF A SINGLE ISOLATED INFESTATION---MUST BE "0"  IF NO ERADICATION PROGRAM IS USED

                     ERADCOST       COL1

                     ROW1              0

          NO. OF YRS AFTER AN ISOLATED INFESTATION BEFORE IT BECOMES A MONETARY FACTOR

                     SKIP           COL1

                     ROW1              5

                PROPORTION OF NEW INFESTATIONS PREVENTED BY BETTER INSP

                     REGEFF         COL1

                     ROW1            0.6

    TOTAL NUMBER OF ISOLATED INFESTATIONS IN EACH SIMULATION -- I.E.    SUM OF ALL YEARS IN 'NI'
```

6

TNI	COL1
ROW1	742

TOTAL AV. NUMBER OF ISOLATED INFESTATIONS ERADICATED BY APHIS/SIM

TOTERAD	COL1
ROW1	0

PRESENT VALUE OF LOSSES -- ALL SIMULATIONS & DECADES -- (COL SIMULATIONS, ROWS=DECADES)

PDF	COL1
ROW1	1130970
ROW2	22761989
ROW3	153500334

PRESENT VALUE APHIS COSTS --

APHISPV	COL1
ROW1	7854292
ROW2	11678256
ROW3	13573323

PRESENT VALUE SUM OF LOSSES & APHIS COSTS --

TPDF	COL1
ROW1	8985262
ROW2	34440245
ROW3	167073657

STATS FOR GM SIMULATION

AV. OVER ALL SIMULATIONS, VALUE IN THOUSANDS OF DOLLARS, FOR YEAR, NOT DISCOUNTED

YR NO	TOTAL NEW INFES EA YR	AREA OF ISO INFES (SQ MI)	TOTAL ADD AREA GENERALLY INFESTED (SQ MI)	VALUE OF TIMBER LOSSES	VALUE OF RECREATION LOSSES	VALUE OF RESIDENTIAL LOSSES	APHIS INSP COSTS	APHIS ERAD COSTS	APHIS TOTAL COSTS	COSTS PLUS LOSSES
1981	9	3	3182	$0	$0	$0	$1,180	$0	$1,180	$1,180
1982	13	10	6544	$0	$0	$0	$1,203	$0	$1,203	$1,203
1983	17	21	10085	$0	$0	$0	$1,228	$0	$1,228	$1,228
1984	21	36	13806	$0	$0	$0	$1,254	$0	$1,254	$1,254
1985	25	60	17707	$0	$0	$0	$1,281	$0	$1,281	$1,281
1986	29	98	21788	$2	$0	$38	$1,309	$0	$1,309	$1,349
1987	27	153	26048	$6	$0	$208	$1,339	$0	$1,339	$1,553
1988	25	201	30489	$10	$0	$412	$1,370	$0	$1,370	$1,792
1989	22	297	35109	$18	$0	$715	$1,402	$0	$1,402	$2,135
1990	18	450	39909	$31	$0	$1,242	$1,435	$0	$1,435	$2,708
1991	14	656	44888	$50	$0	$2,061	$1,470	$0	$1,470	$3,581
1992	14	657	50048	$52	$0	$1,968	$1,505	$0	$1,505	$3,525
1993	18	911	55387	$73	$0	$2,935	$1,542	$0	$1,542	$4,551
1994	22	1146	60906	$95	$0	$4,064	$1,581	$0	$1,581	$5,740
1995	26	1707	66604	$145	$0	$6,139	$1,620	$0	$1,620	$7,904
1996	30	2448	72483	$209	$0	$9,067	$1,661	$0	$1,661	$10,937
1997	34	3670	78541	$315	$1	$13,624	$1,703	$0	$1,703	$15,643
1998	30	5263	84779	$457	$1	$18,941	$1,746	$0	$1,746	$21,146
1999	26	7169	91197	$627	$1	$25,056	$1,791	$0	$1,791	$27,475
2000	22	10738	97794	$944	$2	$28,056	$1,837	$0	$1,837	$30,838
2001	18	16077	104571	$1,420	$3	$31,530	$1,884	$0	$1,884	$34,838
2002	18	22346	111529	$1,979	$4	$42,881	$1,932	$0	$1,932	$46,797
2003	22	33479	118665	$2,972	$7	$46,321	$1,982	$0	$1,982	$51,282
2004	26	49641	125982	$4,416	$10	$64,431	$2,032	$0	$2,032	$70,890
2005	30	74402	133478	$6,629	$15	$88,738	$2,084	$0	$2,084	$97,466
2006	34	91770	141154	$8,176	$18	$117,012	$2,138	$0	$2,138	$127,344
2007	38	133307	149010	$11,886	$27	$164,074	$2,192	$0	$2,192	$178,179
2008	42	199698	157046	$17,820	$40	$245,382	$2,248	$0	$2,248	$265,490
2009	38	288047	165261	$25,722	$58	$359,954	$2,305	$0	$2,305	$388,039
2010	34	431860	173657	$38,588	$87	$536,701	$2,363	$0	$2,363	$577,739

STATS FOR GM SIMULATION

AV. OVER ALL SIMULATIONS, VALUE IN THOUSANDS OF DOLLARS, DISCOUNTED TO PRESENT VALUE

YR NO	TOTAL NEW INFES EA YR	AREA OF ISO INFES (SQ MI)	TOTAL ADD AREA GENERALLY INFESTED (SQ MI)	VALUE OF TIMBER LOSSES	VALUE OF RECREATION LOSSES	VALUE OF RESIDENTIAL LOSSES	APHIS INSP COSTS	APHIS ERAD COSTS	APHIS TOTAL COSTS	COSTS PLUS LOSSES
1981	9	3	3182	$0	$0	$0	$1,073	$0	$1,073	$1,073
1982	13	10	6544	$0	$0	$0	$2,067	$0	$2,067	$2,067
1983	17	21	10085	$0	$0	$0	$2,990	$0	$2,990	$2,990
1984	21	36	13806	$0	$0	$0	$3,846	$0	$3,846	$3,846
1985	25	60	17707	$0	$0	$0	$4,642	$0	$4,642	$4,642
1986	29	98	21788	$1	$0	$21	$5,381	$0	$5,381	$5,403
1987	27	153	26048	$4	$0	$128	$6,068	$0	$6,068	$6,200
1988	25	201	30489	$9	$0	$320	$6,707	$0	$6,707	$7,036
1989	22	297	35109	$16	$0	$624	$7,301	$0	$7,301	$7,941
1990	18	450	39909	$28	$0	$1,102	$7,854	$0	$7,854	$8,985
1991	14	656	44888	$46	$0	$1,825	$8,369	$0	$8,369	$10,240
1992	14	657	50048	$62	$0	$2,452	$8,849	$0	$8,849	$11,364
1993	18	911	55387	$84	$0	$3,302	$9,296	$0	$9,296	$12,682
1994	22	1146	60906	$109	$0	$4,373	$9,712	$0	$9,712	$14,193
1995	26	1707	66604	$143	$0	$5,842	$10,100	$0	$10,100	$16,086
1996	30	2448	72483	$189	$0	$7,815	$10,461	$0	$10,461	$18,466
1997	34	3670	78541	$251	$1	$10,511	$10,798	$0	$10,798	$21,561
1998	30	5263	84779	$333	$1	$13,918	$11,112	$0	$11,112	$25,364
1999	26	7169	91197	$436	$1	$18,014	$11,405	$0	$11,405	$29,856
2000	22	10738	97794	$576	$1	$22,185	$11,678	$0	$11,678	$34,440
2001	18	16077	104571	$768	$2	$26,445	$11,933	$0	$11,933	$39,148
2002	18	22346	111529	$1,011	$2	$31,713	$12,170	$0	$12,170	$44,897
2003	22	33479	118665	$1,343	$3	$36,886	$12,391	$0	$12,391	$50,624
2004	26	49641	125982	$1,791	$4	$43,428	$12,598	$0	$12,598	$57,821
2005	30	74402	133478	$2,403	$5	$51,618	$12,790	$0	$12,790	$66,817
2006	34	91770	141154	$3,089	$7	$61,436	$12,970	$0	$12,970	$77,501
2007	38	133307	149010	$3,996	$9	$73,951	$13,137	$0	$13,137	$91,093
2008	42	199698	157046	$5,232	$12	$90,967	$13,293	$0	$13,293	$109,503
2009	38	288047	165261	$6,853	$15	$113,658	$13,438	$0	$13,438	$133,964
2010	34	431860	173657	$9,065	$20	$144,415	$13,573	$0	$13,573	$167,074

AV. TOTAL NO. OF ISO. INFES. FOR EACH CITY FROM TIME=0 THROUGH END OF DECADE(I)==DECADE_I

N	CITY	STATE	DECADE_1	DECADE_2	DECADE_3	POP78	DIST	LUMLOSS	RECLOSS	RESLOSS	CITYAREA
1	ANNISTON	AL	0	0	2	117000	660	1	1	64.789	635.9
2	BIRMINGHAM	AL	1	2	5	818000	700	1	1	84.507	3408.3
3	FLORENCE	AL	0	0	0	127000	660	1	1	35.211	1270.0
4	GADSDEN	AL	0	1	1	99000	650	1	1	61.620	565.7
5	HUNTSVILLE	AL	1	1	1	293000	630	1	1	53.169	1940.4
6	MOBILE	AL	0	0	1	435000	880	0	0	0.000	2880.8
7	MONTGOMERY	AL	1	2	2	258000	740	0	0	0.000	2047.6
8	TUSCALOOSA	AL	0	0	1	126000	730	1	1	32.746	1354.8
9	PHOENIX	AZ	0	3	3	1293000	1900	0	0	0.000	9438.0
10	TUCSON	AZ	2	2	2	462000	1900	0	0	0.000	9428.6
11	FAYETTEVILLE-SP	AR	1	1	2	161000	930	1	1	31.387	1872.1
12	FORT SMITH	AR	0	0	0	190000	960	1	1	20.073	3454.5
13	LITTLE ROCK-N L	AR	1	1	1	376000	880	0	0	0.000	1516.1
14	PINE BLUFF	AR	0	0	0	86000	880	0	0	0.000	886.6
15	ANAHEIM-SANTA A	CA	0	0	1	1833000	2180	0	0	0.000	795.9
16	BAKERSFIELD	CA	0	1	2	365000	2160	0	0	0.000	8111.1
17	FRESNO	CA	0	0	0	479000	2150	0	0	0.000	6063.3
18	LOS ANGELES-LON	CA	2	4	9	7081000	2160	0	0	0.000	4097.8
19	OXNARD-SIMI VAL	CA	1	1	1	485000	2200	0	0	0.000	1932.3
20	RIVERSIDE-SAN B	CA	0	0	0	1385000	2060	0	0	0.000	28854.2
21	SACRAMENTO	CA	0	0	0	951000	2240	0	0	0.000	3509.2
22	SALINAS-SEASIDE	CA	0	0	0	276000	2280	0	0	0.000	3325.3
23	SAN DIEGO	CA	1	2	4	1744000	2140	0	0	0.000	4415.2
24	SANTA BARBARA-S	CA	0	0	0	292000	2250	0	0	39.179	2781.0
25	SANTA CRUZ	CA	0	0	0	173000	2280	0	0	0.000	449.4
26	SANTA ROSA	CA	0	0	0	274000	2320	0	0	0.000	1670.7
27	STOCKTON	CA	0	0	0	313000	2250	0	0	0.000	1416.3
28	VALLEJO-FAIRFIE	CA	0	0	1	301000	2270	0	0	0.000	1644.8
29	COLORADO SPRING	CO	0	0	0	291000	1360	0	0	40.000	2745.3
30	DENVER-BOULDER	CO	0	1	2	1505000	1350	0	0	118.868	4777.8
31	FORT COLLINS	CO	0	0	0	131000	1380	0	0	0.000	2729.2
32	GREELEY	CO	0	0	0	110000	1340	0	0	10.566	3928.6
33	PUEBLO	CO	0	0	0	122000	1360	0	0	19.245	2392.2
34	BRADENTON	FL	0	0	0	129000	960	0	0	0.000	758.8
35	DAYTONA BEACH	FL	0	0	2	218000	850	0	0	0.000	1084.6
36	FORT LAUDERDALE	FL	0	0	3	882000	1040	0	0	278.039	1244.0
37	FORT MYERS	FL	0	1	1	183000	1020	0	0	0.000	867.3
38	GAINESVILLE	FL	0	2	4	130000	820	0	0	0.000	942.0
39	JACKSONVILLE	FL	0	1	3	702000	760	0	0	0.000	3235.0
40	LAKELAND-WINTER	FL	0	0	1	278000	950	0	0	0.000	1865.8
41	MELBOURNE-TITUS	FL	0	0	0	234000	900	0	0	0.000	1017.4
42	MIAMI	FL	1	2	7	1451000	1080	0	0	0.000	2055.2
43	ORLANDO	FL	2	5	5	610000	900	0	0	0.000	2595.7
44	PANAMA CITY	FL	0	0	0	92000	840	0	0	0.000	748.0
45	PENSACOLA	FL	0	0	1	276000	870	0	0	0.000	1703.7
46	SARASOTA	FL	0	0	0	174000	1000	0	0	0.000	1041.9

AV. TOTAL NO. OF ISO. INFES. FOR EACH CITY FROM TIME=0 THROUGH END OF DECADE(I)==DECADE_I

N	CITY	STATE	DECADE_1	DECADE_2	DECADE_3	POP78	DIST	LUMLOSS	RECLOSS	RESLOSS	CITYAREA
47	TALLAHASSEE	FL	0	0	0	140000	800	0	0	0.000	1284.40
48	TAMPA-ST PETERS	FL	2	3	8	1396000	940	0	0	0.000	2068.15
49	W PALM BEACH-BA	FL	0	0	1	487000	1000	0	0	0.000	2063.56
50	ATLANTA	GA	2	8	21	1852000	600	0	0	0.000	4287.04
51	AUGUSTA	GA	1	1	2	291000	560	0	0	0.000	1721.89
52	COLUMBUS	GA	0	0	1	228000	720	0	0	0.000	1096.15
53	MACON	GA	0	0	1	243000	660	0	0	0.000	1404.62
54	SAVANNAH	GA	1	1	3	219000	650	0	0	0.000	1394.90
55	BLOOMINGTON	ID	0	0	1	92000	460	1	1	83.509	386.55
56	BOISE CITY	ID	0	0	0	153000	1880	1	1	49.123	1092.86
57	BLOOMINGTON-NOR	IL	1	1	3	119000	560	1	1	36.594	1178.22
58	CHAMPAIGN-URBAN	IL	0	1	3	164000	530	1	1	60.870	976.19
59	CHICAGO	IL	14	48	122	7030000	500	1	1	683.696	3725.49
60	DECATUR	IL	0	0	1	128000	570	1	1	80.072	579.19
61	KANKAKEE	IL	0	0	2	97000	520	1	1	51.449	683.10
62	PEORIA	IL	0	3	8	361000	600	1	1	72.826	1796.02
63	ROCKFORD	IL	1	1	5	269000	580	1	1	121.014	805.39
64	SPRINGFIELD	IL	0	0	2	185000	620	1	1	56.522	1185.90
65	ANDERSON	IN	0	2	2	138000	400	1	1	109.386	455.45
66	ELKHART	IN	0	0	0	136000	4000	1	1	83.032	591.30
67	EVANSVILLE	IN	2	3	5	295000	550	1	1	53.069	2006.80
68	FORT WAYNE	IN	1	6	6	376000	360	1	1	76.534	1773.58
69	GARY-HAMMOND-FA	IN	2	10	16	648000	470	1	1	248.014	943.23
70	INDIANAPOLIS	IN	1	10	10	1156000	370	1	1	134.296	3107.53
71	KOKOMO	IN	0	0	0	104000	420	1	1	67.509	556.15
72	LAFAYETTE-W. LA	IN	0	1	1	115000	460	1	1	83.032	500.00
73	MUNCIE	IN	0	2	2	128000	380	0	0	0.000	395.06
74	SOUTH BEND	IN	0	0	2	281000	430	1	1	109.747	924.34
75	TERREHAUTE	IN	0	0	0	174000	820	1	1	41.516	1513.04
76	CEDAR RAPIDS	IA	0	0	0	167000	700	0	0	86.940	716.74
77	DAVENPORT-ROCK	IA	2	3	3	374000	650	0	0	0.000	1700.00
78	DES MOINES	IA	1	1	1	334000	800	0	0	0.000	1139.93
79	DUBUQUE	IA	0	0	0	93000	670	1	1	58.955	588.61
80	IOWA CITY	IA	1	1	1	78000	670	0	0	58.955	493.67
81	SIOUX CITY	IA	0	1	1	120000	900	0	0	39.925	1121.50
82	WATERLOO-CEDAR	IA	1	1	1	139000	740	0	0	89.925	576.76
83	KANSAS CITY	KS	1	2	4	1325000	870	1	1	147.710	3423.77
84	LAWRENCE	KS	0	0	0	65000	940	0	0	53.053	467.63
85	TOPEKA	KS	0	0	0	187000	900	0	0	40.458	1764.15
86	WICHITA	KS	0	0	0	398000	1000	0	0	61.450	2472.05
87	LEXINGTON-FAYET	KY	0	5	7	300000	400	1	1	69.858	1522.84
88	LOUISVILLE	KY	2	4	11	887000	440	1	1	224.823	1399.05
89	OWENSBORO	KY	0	1	3	81000	530	1	1	61.762	465.52
90	ALEXANDRIA	LA	0	0	0	140000	1040	0	0	0.000	2000.00
91	BATON ROUGE	LA	1	4	4	445000	1020	0	0	92.440	1654.28
92	LAFAYETTE	LA	0	0	0	134000	1080	0	0	160.825	286.32

AV. TOTAL NO. OF ISO. INFES. FOR EACH CITY FROM TIME=0 THROUGH END OF DECADE(I)==DECADE_I

N	CITY	STATE	DECADE_1	DECADE_2	DECADE_3	POP78	DIST	LUMLOSS	RECLOSS	RESLOSS	CITYAREA
93	LAKE CHARLES	LA	1	1	2	158000	1140	0	0	48.454	1120.57
94	MONROE	LA	1	1	1	131000	970	0	0	0.000	645.32
95	NEW ORLEANS	LA	0	2	4	1141000	1010	0	0	0.000	1980.90
96	SHREVEPORT	LA	0	0	1	356000	1030	0	0	0.000	2357.62
97	ANN ARBOR	MI	5	5	5	255000	310	1	1	123.944	724.43
98	BATTLE CREEK	MI	0	2	2	184000	390	1	1	50.704	1277.78
99	BAYCITY	MI	2	4	4	122000	360	0	0	94.718	453.53
100	DETROIT	MI	36	43	43	4386000	300	1	1	392.958	3930.11
101	FLINT	MU	2	3	3	521000	340	1	1	153.521	1194.95
102	GRAND RAPIDS	MI	2	7	10	585000	420	1	1	142.606	1444.44
103	JACKSON	MI	1	1	1	150000	340	1	1	75.704	697.67
104	KALAMAZOO-PORTA	MI	1	1	1	270000	400	1	1	80.986	1173.91
105	LANSING-E. LANS	MI	2	4	4	458000	360	0	0	70.423	2290.00
106	MUSKEGON-NORTON	MI	2	5	6	180000	450	1	1	60.915	1040.46
107	SAGINAW	MI	2	5	5	228000	350	0	0	0.000	820.14
108	DULUTH-SUPERIOR	MN	0	1	1	266000	840	0	0	13.139	7388.89
109	MINNEAPOLIS-ST	MN	4	10	14	2063000	800	1	1	159.854	4710.05
110	ROCHESTER	MN	0	0	1	92000	760	1	1	50.365	666.67
111	ST CLOUD	MN	0	0	0	161000	880	1	1	26.277	2236.11
112	BILOXI-GULFPORT	MS	0	0	1	176000	950	0	0	0.000	1517.24
113	JACKSON	MS	0	0	1	299000	900	1	1	60.269	1670.39
114	PASCAGOULA-MOSS	MS	0	0	0	118000	930	0	0	0.000	766.23
115	COLUMBIA	MO	0	1	3	91000	760	1	1	48.689	700.00
116	SPRINGFIELD	MO	0	0	0	205000	860	1	1	58.052	1322.58
117	ST JOSEPH	MO	1	1	2	100000	870	0	0	44.569	840.34
118	ST LOUIS	MO	6	11	22	2386000	660	1	1	180.524	4950.21
119	BILLINGS	MT	0	0	0	104000	1480	0	0	0.000	2736.84
120	GREAT FALLS	MT	0	0	1	86000	1660	0	0	11.852	2687.50
121	LINCOLN	NE	0	0	1	186000	930	0	0	81.955	853.21
122	OMAHA	NE	0	2	4	582000	900	0	0	142.105	1539.68
123	LAS VEGAS	NV	1	1	1	377000	1940	0	0	0.000	8195.65
124	RENO	NV	0	0	0	163000	2120	0	0	0.000	6520.00
125	ALBUQUERQUE	NM	0	0	0	409000	1540	0	0	0.000	4987.80
126	LAS CRUCES	NM	0	0	0	85000	1640	0	0	8.966	3269.23
127	ASHEVILLE	NC	0	1	1	172000	440	1	1	54.676	1131.58
128	BURLINGTON	NC	0	0	0	98000	350	0	0	83.094	424.24
129	CHARLOTTE-GASTO	NC	2	6	8	606000	430	0	0	0.000	1549.87
130	FAYETTEVILLE	NC	0	3	3	233000	420	0	0	127.338	658.19
131	GREENSBORO-WINS	NC	4	10	10	779000	360	0	0	0.000	3232.37
132	RALEIGH-DURHAM	NC	3	8	8	494000	360	0	0	0.000	1573.25
133	WILMINGTON	NC	0	2	4	130000	480	0	0	0.000	1040.00
134	BISMARK	ND	0	1	1	76000	1220	0	0	10.545	2620.69
135	FARGO-MOORHEAD	ND	0	0	0	132000	1000	0	0	0.000	2808.51
136	GRAND FORKS	ND	1	1	1	100000	1030	0	0	0.000	3448.28
137	CANTON	OH	0	0	0	404000	180	1	1	150.362	973.49
138	CINCINNATTI	OH	3	15	15	1389000	360	1	1	231.984	2170.31

AV. TOTAL NO. CF ISO. INFES. FOR EACH CITY FROM TIME=0 THROUGH END OF DECADE(I)==DECADE_I 10

N	CITY	STATE	DECADE_1	DECADE_2	DECADE_3	POP78	DIST	LUMLOSS	RECLOSS	RESLOSS	CITYAREA
139	COLUMBUS	OH	8	8	8	1089000	260	1	1	160.145	2463.80
140	DAYTON	OH	9	11	11	834000	320	1	1	176.812	1709.02
141	HAMILTON-MIDDLE	OH	1	6	7	256000	400	1	1	192.754	481.20
142	LIMA	OH	1	1	1	212000	330	0	0	44.565	1723.58
143	LORAIN-ELYRIA	OH	1	1	1	271000	220	1	1	193.116	508.44
144	MANESFIELD	OH	2	2	2	130000	230	1	1	95.290	494.30
145	MODESTO	CA	0	0	0	246000	2240	0	0	0.000	1576.92
146	SAN FRANCISCO-O	CA	0	1	5	3184000	2420	0	0	478.731	2481.68
147	SAN JOSE	CA	0	0	1	1232000	2280	0	0	0.000	1316.24
148	SPRINGFIELD	OH	1	1	1	183000	300	1	1	79.348	835.62
149	TOLEDO	OH	11	11	11	776000	270	0	0	0.000	2185.92
150	ENID	OK	0	0	0	63000	1000	0	0	41.603	577.98
151	LAWTON	CK	0	0	1	120000	1160	0	0	41.603	1100.92
152	OKLAHOMA CITY	OK	1	3	4	789000	1070	0	0	83.969	3586.36
153	TULSA	OK	1	2	4	629000	980	1	1	40.840	5878.50
154	EUGENE-SPRINGFI	OR	1	1	1	258000	2240	0	0	21.154	4690.91
155	PORTLAND	OR	0	1	1	1140000	2200	0	0	118.077	3713.36
156	SALEM	OR	0	0	1	226000	2180	0	0	43.846	1982.46
157	CHARLESTOWN-N.C	SC	1	2	8	389000	560	0	0	0.000	2646.26
158	COLUMBIA	SC	1	1	4	380000	520	0	0	0.000	1490.20
159	GREENVILLE-SPAR	SC	0	5	9	541000	470	0	0	0.000	2172.69
160	RAPID CITY	SD	0	0	0	91000	1240	0	0	5.474	6066.67
161	SIOUX FALLS	SD	0	0	0	103000	930	0	0	45.985	817.46
162	CHATTANOOGA	TN	0	2	8	401000	580	1	1	68.953	2099.48
163	CLARKSVILLE-HOP	TN	0	0	2	148000	580	1	1	41.516	1286.96
164	JOHNSON CITY-KI	TN	2	2	2	411000	370	1	1	51.264	2894.37
165	KNOXVILLE	TN	1	5	14	456000	470	1	1	99.639	1652.17
166	MEMPHIS	TN	1	1	3	889000	760	1	1	139.350	2303.11
167	NASHVILLE-DAVID	TN	2	4	13	786000	570	1	1	68.231	4158.73
168	ABILENE	TX	0	1	1	132000	1500	0	0	17.021	2750.00
169	AMARILLO	TX	0	0	0	158000	1300	0	0	30.851	1816.09
170	AUSTIN	TX	0	1	1	478000	1280	0	0	60.638	2795.32
171	BEAUMONT-PORT A	TX	0	1	1	364000	1160	0	0	58.511	2206.06
172	BROWNSVILLE-HAR	TX	0	0	0	177000	1480	0	0	0.000	898.48
173	BRYAN-COLLEGE S	TX	0	0	0	76000	1220	0	0	0.000	575.76
174	CORPUS CHRISTI	TX	0	0	0	302000	1400	0	0	70.567	1517.59
175	DALLAS-FORT WOR	TX	3	8	12	2720000	1150	0	0	113.475	8500.00
176	EL PASO	TX	1	1	1	443000	1640	0	0	0.000	1077.86
177	GALVESTON-TX CI	TX	0	1	1	198000	1230	0	0	173.759	404.08
178	HOUSTON	TX	0	1	4	2595000	1220	0	0	131.206	7013.51
179	KILLEEN-TEMPLE	TX	0	0	1	209000	1240	0	0	35.461	2090.00
180	LAREDO	TX	0	0	0	86000	1480	0	0	0.000	3307.69
181	LONGVIEW-MARSHA	TX	0	0	0	134000	1070	1	1	39.716	1196.43
182	LUBBOCK	TX	0	0	0	200000	1350	0	0	79.433	892.86
183	MCALLEN-PHARR-E	TX	1	2	2	236000	1500	0	0	0.000	[illegible]
[illegible]	MIDLAND	TX	0	0	0	74000	1420	0	0	27.305	[illegible]

AV. TOTAL NO. OF ISO. INFES. FOR EACH CITY FROM TIME=0 THROUGH END OF DECADE(I)==DECADE_I

N	CITY	STATE	DECADE_1	DECADE_2	DECADE_3	POP78	DIST	LUMLOSS	RECLOSS	RESLOSS	CITYAREA
185	ODESSA	TX	0	0	0	106000	1440	0	0	40.426	929.82
186	SAN ANGELO	TX	0	0	0	77000	1380	0	0	0.000	1509.80
187	SAN ANTONIO	TX	0	0	4	1038000	1340	0	0	0.000	2556.65
188	SHERMAN-DENISON	TX	0	0	0	85000	1100	1	1	31.560	955.06
189	TEXARKANA	TX	0	0	1	119000	1010	1	1	20.922	2016.95
190	TYLER	TX	0	0	0	114000	1070	1	1	42.199	957.98
191	WACO	TX	0	0	0	161000	1200	0	0	57.447	993.83
192	WICHITA FALLS	TX	0	0	0	129000	1150	0	0	27.305	1675.32
193	PROVO-OREGON	UT	0	0	0	185000	1700	0	0	0.000	2102.27
194	SALT LAKE CITY	UT	0	0	0	843000	1760	0	0	0.000	8781.25
195	LYNCHBURG	VA	2	2	2	148000	270	1	1	38.489	1383.18
196	NEWPORT NEWS-HA	VA	0	1	1	361000	290	0	0	0.000	649.28
197	NORFOLK-VA BEAC	VA	5	7	7	830000	320	0	0	0.000	1333.33
198	PETERSBURG-COLO	VA	1	1	1	128000	280	0	0	0.000	805.03
199	RICHMOND	VA	2	2	2	612000	240	0	0	0.000	2177.94
200	ROANOKE	VA	1	1	1	211000	260	0	0	0.000	1159.34
201	RICHLAND-KENNEW	WA	1	1	1	128000	2040	0	0	0.000	3282.05
202	SEATTLE-EVERETT	WA	0	0	0	1458000	2160	0	0	129.502	4313.61
203	SPOKANE	QA	0	0	1	320000	1940	0	0	0.000	1818.18
204	TACOMA	WA	0	1	1	437000	2170	0	0	96.935	1727.27
205	YAKIMA	WA	0	0	0	159000	2100	0	0	0.000	4297.30
206	CHARLESTON	WV	1	1	1	261000	260	1	1	74.552	1254.81
207	HUNTINGTON-ASHL	WV	3	3	3	300000	290	1	1	60.573	1775.15
208	PARKERSBURG-MAR	WV	0	0	0	158000	200	1	1	44.444	1274.19
209	APPLETON-OSHKOS	WI	1	1	1	291000	580	0	0	74.368	1412.62
210	EAU CLAIRE	WI	0	0	1	126000	720	0	0	26.715	1792.70
211	GREEN BAY	WI	1	2	2	178000	560	1	1	120.578	532.93
212	JANESVILLE-BELO	WI	0	1	2	134000	580	1	1	67.148	720.43
213	KENOSHA	WI	0	3	3	124000	510	1	1	165.704	270.15
214	LA CROSSE	WI	0	0	0	90000	700	1	1	69.314	468.75
215	MADISON	WI	0	1	3	319000	600	1	1	94.224	1222.22
216	MILWAUKEE	WI	4	10	28	1417000	540	1	1	353.791	1445.92
217	RACINE	WI	1	2	2	177000	520	1	1	189.531	337.14

APPENDIX C

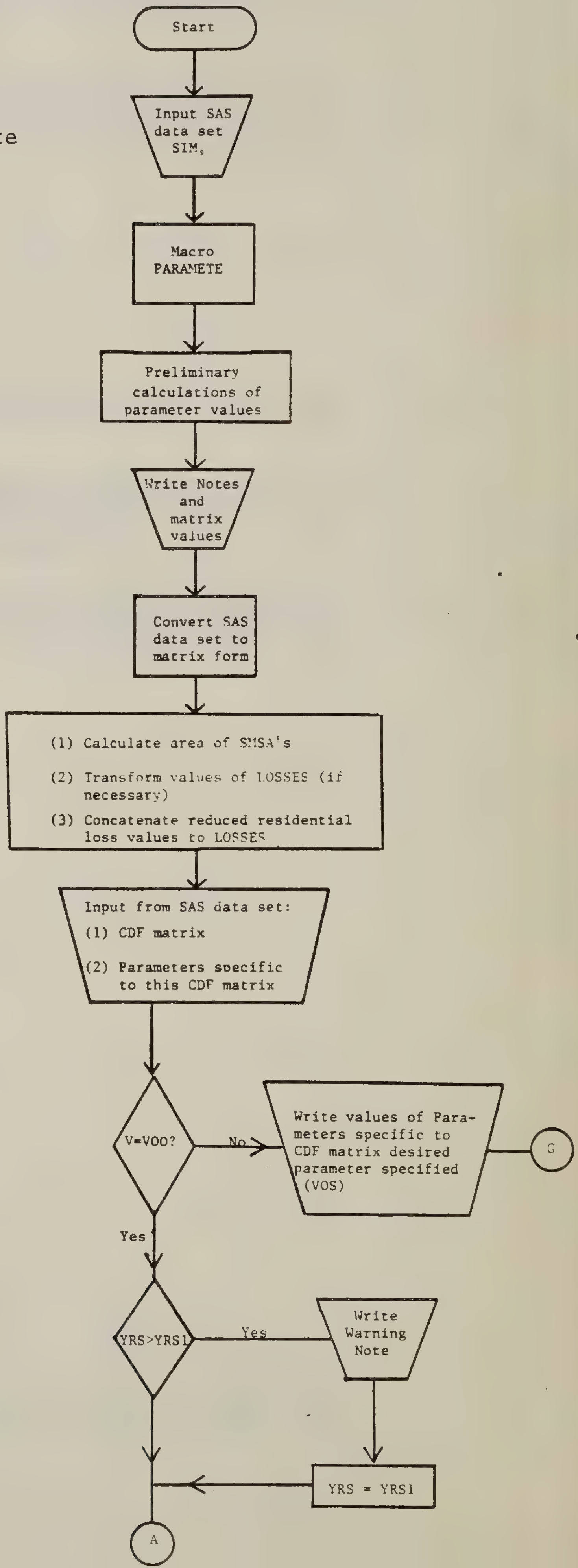
PROGRAM DESCRIPTION

AND FLOW CHARTS

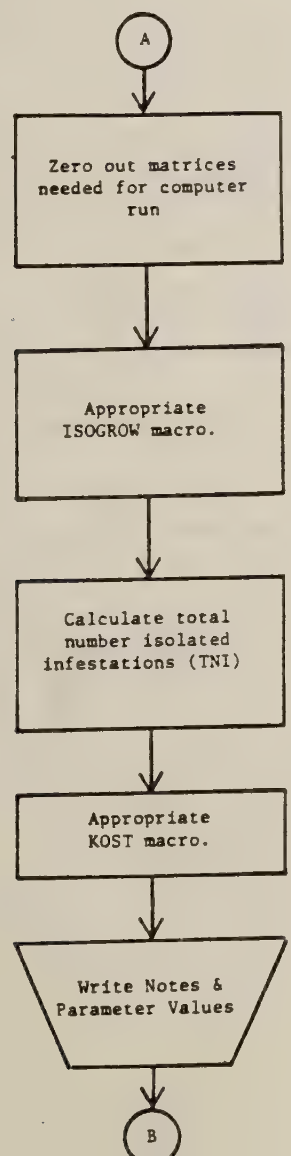
PROGRAM DESCRIPTION AND FLOW CHARTS

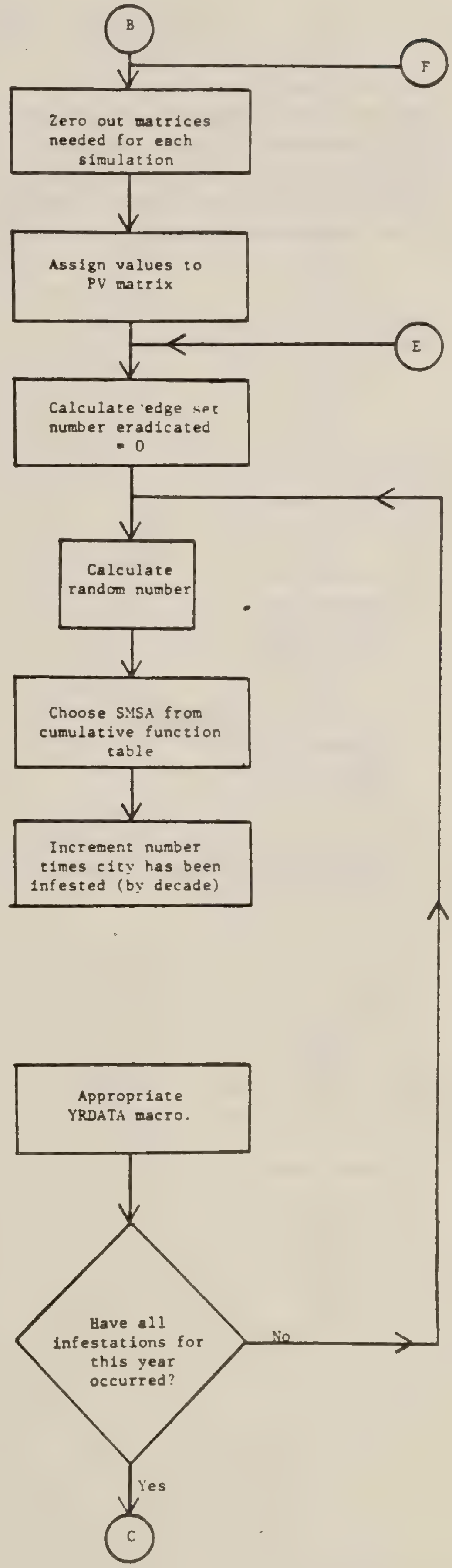
Main Program

The main program reads the appropriate SAS data set to input data about the SMSA's, then converts to the PROC MATRIX procedure. After calling macros PARAMETE, ISOCOST and KOST, the main program does preliminary conversion of data values and writes system parameters and relevant summary statistics to the output file. It then creates appropriate matrices needed by the program before starting the actual simulation. After starting the simulation, appropriate matrices are zeroed out. Then for each year of the planning horizon, the location of the LE is calculated. For each isolated infestation which occurs each year, a city is randomly selected, macro YRDATA called, and the number of isolated infestations for the year have occurred, the total number of infestations eradicated and associated costs are tallied. APHIS inspection and eradication costs and losses are calculated. Losses and total APHIS costs are then converted to a future value basis, saving those future values which correspond to the end of each decade.

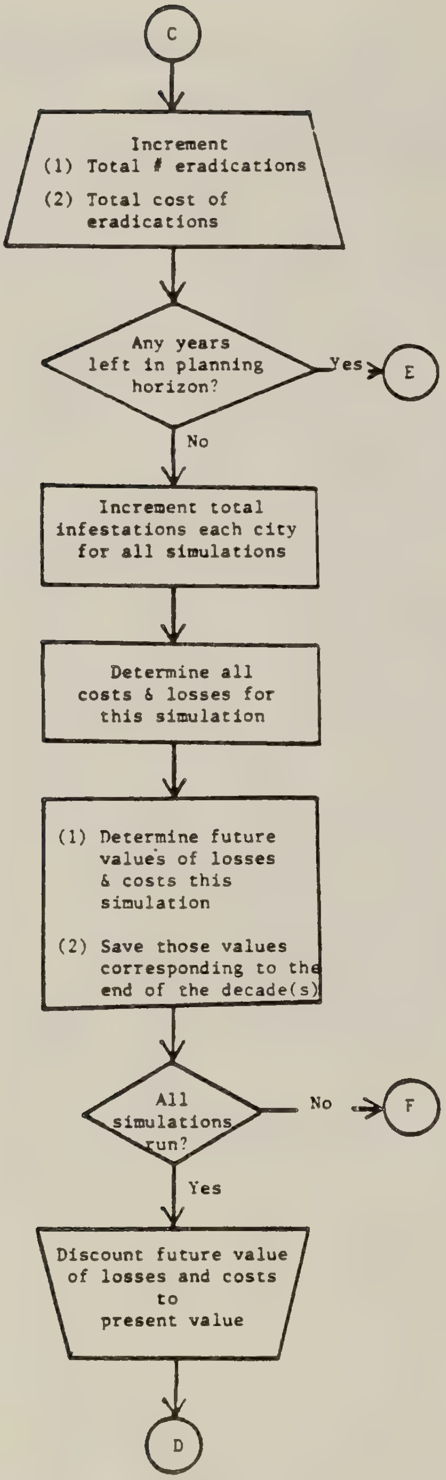


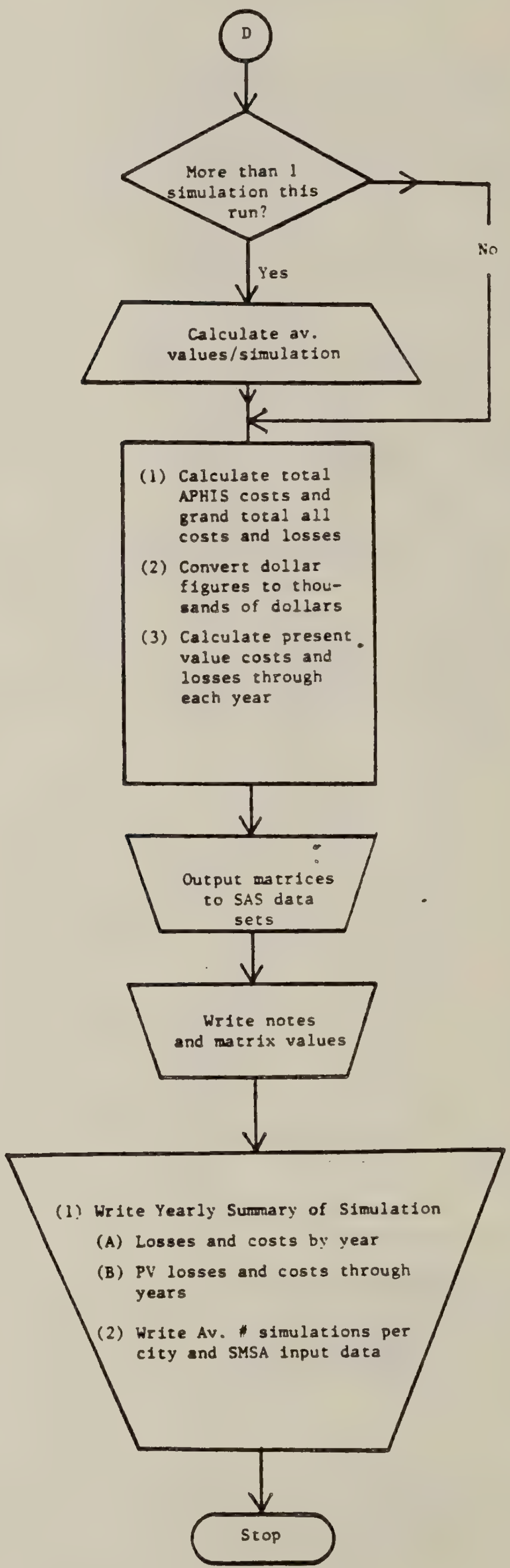
These values are then discounted to determine the present values of losses and costs for the various planning horizons (by decade). If more than one simulation occurs in the computer run, appropriate statistics are then converted to an average per simulation basis. Results are then placed in a format suitable for output, and dollar values converted to a thousand dollar basis. Output matrices are output to a SAS data set. Additional notes and statistics are written to the output file. Finally, data sets are written to the output file which summarize statistics by year and give the number of isolated infestations for each city by decade along with data on each SMSA.





PROGRAM DESCRIPTION AND FLOW CHARTS--Continued





PROGRAM DESCRIPTION AND FLOW CHART--Continued

Macro PARAMETE

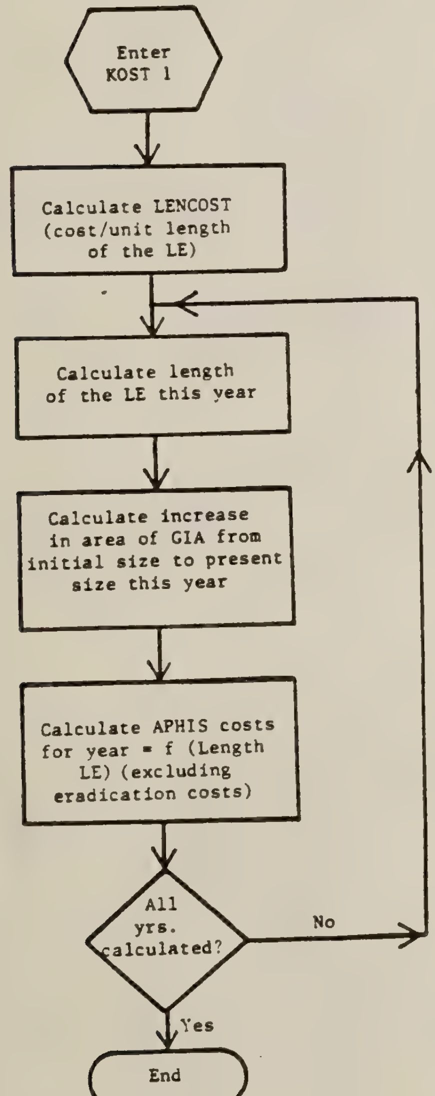
This macro contains a note describing the scenerio for the computer output. It also contains input values for all parameters in the simulation.

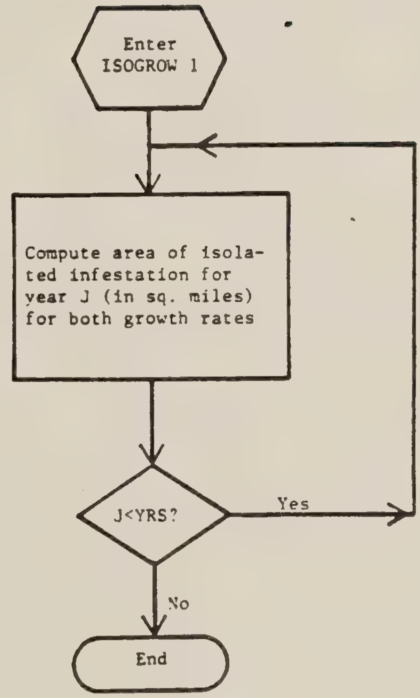
Macro KOST 1

This macro calculates the increase in size of the GIA over the planning horizon and all APHIS costs excluding eradication costs.

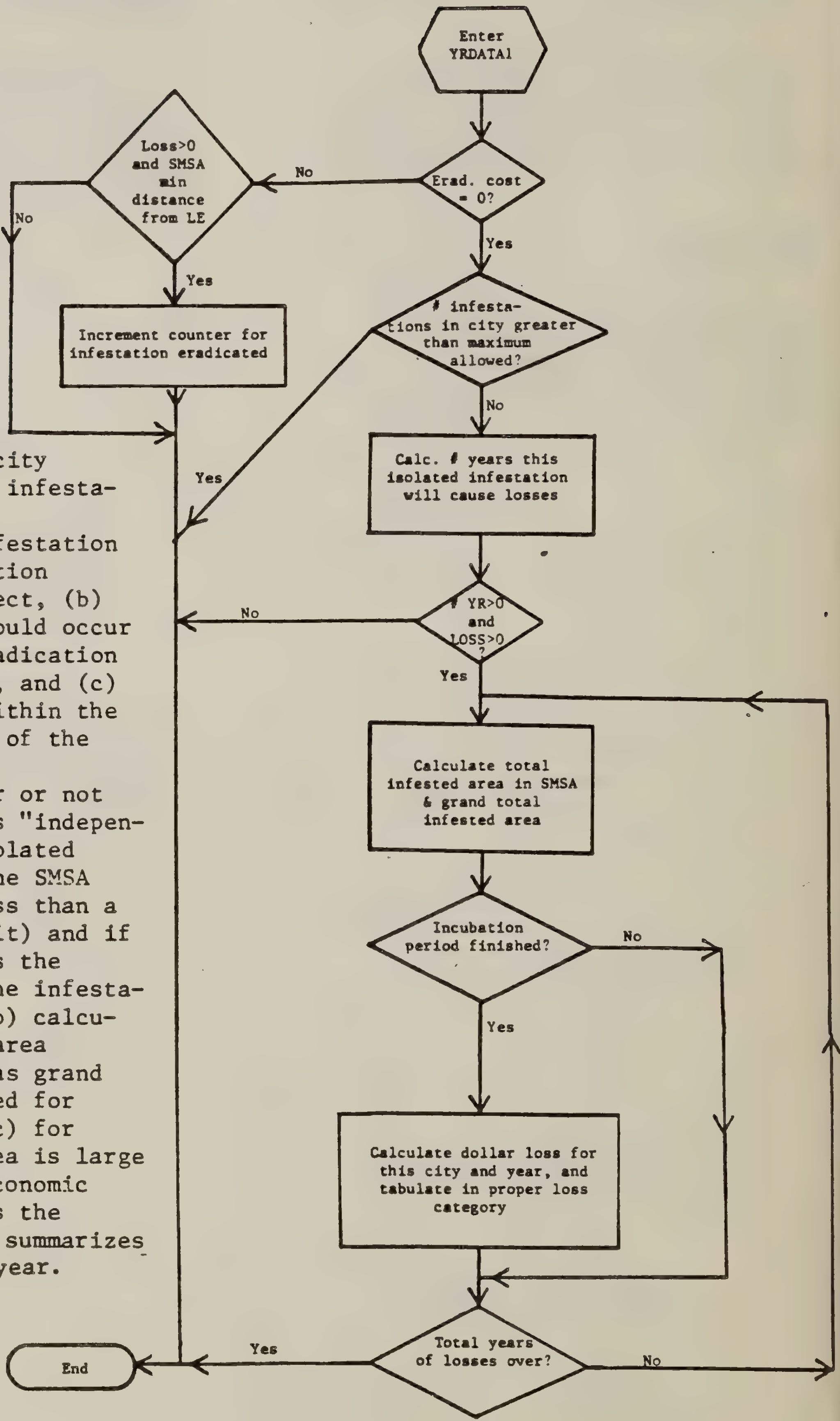
Macro ISOGROW 1

This macro calculates the size of an isolated infestation at any given time given the infestation's initial size, two possible rates of growth, and maximum period for growth (planning horizon).





PROGRAM DESCRIPTION AND FLOW CHARTS--Continued



Macro YRDATA1

This macro takes the city receiving an isolated infestation and

(1) eradicates the infestation if (a) an eradication program is in effect, (b) economic losses would occur in the area if eradication is not undertaken, and (c) the city is not within the required distance of the leading edge, or

(2) determines whether or not the infestation is "independent" of other isolated infestations in the SMSA (the number is less than a predetermined limit) and if so, (a) determines the number of years the infestation will grow, (b) calculates total city area infested as well as grand total area infested for all SMSA's, and (c) for years in which area is large enough to cause economic losses, calculates the economic loss and summarizes it in a table by year.

APPENDIX D

SOURCE PROGRAM LISTING

```
2                    S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

                                                                              00000150

OPTIONS PAGESIZE=50 NODATE;                                                   00000160
TITLE;                                                                        00000170
*******************   GYMSIM1   -- GYPSY MOTH SIMULATION NO. 1;              00000180
                 *****(1);       MACRO PARAMETE                               00000190
       * READ IN VALUES OF PARAMETERS & CREATE BLANK MATRICES;                00000200
NOTE        HOUSEHOLD GOODS INSPECTION PROGRAM ONLY;                          00000210
NOTE           REGULATION EFFICIENCY = 100 PERCENT;                           00000220
NOTE           35 PERCENT CF CALL-IN'S INSPECTED;                             00000230
NOTE                  FC = $1,158,000;                                        00000240
NOTE               VC = $6.94 / SQ. MILE;                                     00000250
NOTE        REGULATION EFFICIENCY (REGEFF) = 60 PERCENT;                      00000260
NOTE SKIP=5;                                                                  00000270
R=.1;                        * DISCOUNT FACTOR;                               00000280
NS=1;                        * # SIMS (TO GET PDF);                           00000290
YRS=30;                               * YRS IN SIM;                           00000300
   DECADES=INT((YRS+9)#/10);    * CAL # DECADES IN SIMULATION;                00000310
SEED=1111111;                * RANDOM # GEN (7 DIGIT ODD INTEGER);            00000320
GR=.25/.50;                  * SLOW & FAST GROWTH RATES ISO INFE;             00000330
   GR=GR+1;                                                                   00000340
AREA0=200;                   * INITIAL SIZE ISOLATED INFES (ACRES);           00000350
NINFMAX=100;  * ALL ISOLATED INFESTATIONS IN A CITY ABOVE THIS                00000360
              * AMOUNT DO NOT INCREASE AREA OF DAMAGES;                       00000370
PART=.50;     * PROPORTION OF CITY AREA RECEIVING FULL RESIDENTIAL            00000380
              * LOSS FUNCTION;                                                00000390
FRACT=.25;  * PROPORTION OF LOSS FUNCTION RECEIVED BY REMAINDER OF CITY;00000400
COSTNAT=0;    * COST IS FUNCTION OF LENGTH OF LEADING EDGE;                   00000410
              * FIXED COSTS - DON'T CHANGE OVER TIME;                         00000415
FC =1158000;                                                                  00000420
            *COST IS FUNCTION OF AREA IN EXPANDED PORTION OF GIA;             00000425
VC=6.94;                                                                      00000430
      * I.E. AREA(YR_I) - AREA(YR=0);                                         00000440
             *COST TO ERADICATE EACH ISO INFESTATION;                         00000445
ERADCOST= 0;                                                                  00000450
BORDER=100;                  * DIST IN FRONT OF LE WHERE NO ERAD;             00000460
V00=10/10;          * SPEED OF LE IN THIS RUN;                                00000470
V0=10/10;              * SPEED OF LE IN BASE RUN;                             00000480
WIDTH=103/0;                    * WIDTH OF SECTOR (DEGREES);                  00000490
SKIP=5;  * NO. YRS BEFORE ISO INFES IS MONETARY FACTOR;                       00000500
                 * ADJUSTMENT FACTOR FOR LUM. REC. & REC LOSSES;              00000510
```

```
                             *        -- "1" IF NO CHANGE FROM INFO IN MATRIX;   00000520
ADJF=3584 8.1 478/3584 8.1 10682;                                                00000530
ADJEFF=.025 .025 .025/.025 .025 .025; * PRO ISO AREA HAVING LUM,                 00000540
          * RES LOSSES & ADDITIONAL PROP FACTOR FOR AREA SAVED FROM GIA;00000550
                    * NO. NEW INFESTATIONS FOR THE SIMULATIONS                   00000560
                    * DETERMINED BY EXPERT OPINION (APHIS);                      00000570
                 * # ISO INFESTATIONS WITH PRESENT INSPECTION PROGRAM;           00000580
NI=20 30 40 50 60 70 65 60 50 40                                                 00000590
   30 30 40 50 60 70 80 70 60 50                                                 00000600
   40 40 50 60 70 80 90 100 90 80;                                               00000610
               * # ISO INFESTATIONS WITHOUT PRESENT PROGRAM;                     00000620
NI=23 33 43 53 63 73 68 63 54 44                                                 00000630
   34 34 44 54 64 74 85 75 65 55                                                 00000640
   45 45 55 65 76 86 96 106 96 86;                                               00000650
REGEFF=.60;         * PERCENTAGE OF NEW INFESTATIONS ELIMINATED;                 00000660
                    * CHOOSE CORRECT MACROS TO USE IN THIS RUN;                  00000670
ISOGROW=1;                                                                       00000680
KOST=1;                                                                          00000690
YRDATA=1;                                                                        00000700
%                                                                                00000710
```

```
                                                                          00000720
                 *****(2)$      MACRO KOST1                               00000730
                  * COST CURRENT INSP RROG F(AREA GENERALLY INFEST)$      00000740
                  * COST RETARDING SPEED OF LEADING EDGE F(LENGTH LE)$00000750
LENCOST=COSTNAT#/((EDGE0#WIDTH)(+,))$ * COST FACTOR=LIN F(LENGTH LE)$     00000760
EDGE=EDGE0$                                                               00000770
DO J=1 TO YRS$                                                            00000780
   EDGE=EDGE+ V$                                                          00000790
               * AREA NAT SPREAD=K*PI*  (EDGE(I)**2 - EDGE(0)**2)$        00000800
   ACRESNAT(1,J)=(WIDTH#(EDGE+EDGE0)#(EDGE-EDGE0))(+,)*                   00000810
      3.14159#/360$                                                       00000820
   INSPCOST(1,J)=FC+VC#ACRESNAT(1,J)+((EDGE#WIDTH)(+,))*LENCOST$          00000830
END$ %                                                                    00000840
```

```
                                                                        00000850

                  *****(3);      MACRO ISOGROW1                         00000860
* AREAS COVERED BY 'HI' & 'LOW' GROWTH RATE OF GM FOR A GIVEN INITIAL ; 00000870
* AREA, A(I). ANSWER IS FN OF TIME;                                     00000880
     AREA(,1)=AREA0*GR#/640;     * CONVERT ACREA TO SQ MI;              00000890
     DO K=2 TO YRS;                                                     00000900
        AREA(,K)=AREA(,K-1)#GR;                                         00000910
     END;                                                               00000920
     %                                                                  00000930
```

```
                    *****(4);      MACRO YRDATA1
                      * (1) ERADCOST=0 IMPLIES NO ERADICATION (POSSIBLE
                      *      AREA LOSS);
                      * (2) LOSS FN>0 IMPLIES AREA LOSS;
                    * FUNCTION CALCULATES LOSSES IN ISOLATED INFES.
                    * AREA BUT DOES NOT INCLUDE ERADICATION COSTS;
IF (ERADCOST=0) THEN DO;
 IF (NCITYINF(DECADES,MID)<=NINFMAX) THEN DO;
   NYR=INT((DIST(MID,1)-EDGE(VR(MID,1),1))*/V(VR(MID,1),1));
   IF NYR > (YRS+1-J) THEN NYR=YRS+1-J;
   IF (LOSSES(MID,4)>0 & NYR>0) THEN DO;
      JL=J-1;
      DO L=1 TO NYR;
         YRAMT=0;
         JL=JL+1;
         CITYAOT(MID,JL)=CITYAOT(MID,JL)+AREA(DUMMY(MID,1),L);
         TOTACRES(1,JL)=TOTACRES(1,JL)+AREA(DUMMY(MID,1),L);
         IF L>SKIP THEN DO;
 * LOSS FROM ISO INFES YR J CITY K IN YR (J+L) SIM I, UNDISCOUNTED;
            DO LL=1 TO 3;
               IF (LL=3&CITYAOT(MID,JL)=>CITYAREA(MID,1)) THEN
               YRLOSS(LL,JL)=YRLOSS(LL,JL)+LOSSES(MID,LL+1)*
               AREA(DUMMY(MID,1),L);
                  ELSE YRLOSS(LL,JL)=YRLOSS(LL,JL)+LOSSES(MID,LL)*
                  AREA(DUMMY(MID,1),L);
            END;
         END;
      END;
   END;

  END;
END;
                  * ERADICATION PROGRAM CARRIED OUT ONLY IF ERATCOST>0;
ELSE
   IF (LOSSES(MID,4)>0 & (DIST(MID,1)-(J-.5)*V(VR(MID,1),1)>BORDER))
   THEN NIERAD=NIERAD+1;
%
```

```
        ********************************* PROCEDURE OPTIONS MAIN **********;
        DATA SIM;              * INPUT SAS DATA SET;
           SET APHIS2.INFO;

NOTE: DATA SET WORK.SIM HAS 217 OBSERVATIONS AND 10 VARIABLES. 224 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.25 SECONDS AND 180K.

        PROC MATRIX; I=0; J=0;
        *D                     I-INDEX FOR SIM # (FOR PDF);
        *D                     J-INDEX FOR YEAR#  SIM(I);
        *D                     K-INDEX FOR ISOLATED INFEST # IN YR(J);
        *D                     L-INDEX FOR FV LOSS CITY(K) THROUGH THE YRS;
        NOTE *******************;
        PARAMETE; ****MACRO(1);
        FETCH CITYAREA DATA=SIM(KEEP=CITYAREA);
           CITYAREA=CITYAREA*PART;   *FRACTION OF CITY GIVEN ALL RES LOSS;
        FETCH DIST   DATA=SIM (KEEP=DIST);
           NR=NROW(DIST);              * # SMSA'S;
        FETCH POP78  DATA=SIM (KEEP=POP78);
        FETCH LOSSES DATA=SIM (KEEP=LUMLOSS RECLOSS RESLOSS);
        LF=ADJF#ADJEFF;
              DO I=1 TO 3;  * PROPORTION LOSS FACTOR;
                 IF LF(1,I)^=1 THEN LOSSES(,I)=LOSSES(,I)*LF(1,I);
              END;
              LOSSES=LOSSES\\LOSSES(,3)*FRACT;
                             * SPREAD RATE: 0 UNSUSECPTIBLE,  1 SUSC.,  2 HIGHLY;
        FETCH DUMMY  DATA=SIM (KEEP=DUMMY);
                             * LEADING EDGE - SLOW OR FAST = 0 OR 1;
        FETCH VR     DATA=SIM (KEEP=VR);
        FETCH CUMNUM DATA=APHIS2.PROB;
        FETCH PARA DATA=APHIS2.PARA1;
           EDGE0=PARA(1:2,1);
           V=PARA(3:4,1);
           KR=PARA(5,1);
           YRS1=PARA(6,1);
              IF (YRS>YRS1) THEN DO;
                 NOTE TOO MANY YEARS REQUESTED -- LIMIT IS ......;
                 PRINT YRS1;
                 YRS=YRS1;
```

```
            END;                                                         00001690
         IF V^=V00 THEN DO;                                              00001700
            NOTE PLANNED SPEED OF LE NOT SAME AS SPEED USED IN DERIVING PDF --00001710
      RUN ABORTED;                                                       00001720
            NOTE INITIAL RADIUS OF LE, PDF SPEED OF LE, DESIRED SPEED, MIN DIS00001730
      TANCE FOR DISTANCE TO AFFECT PROB, TOTAL YEARS;                    00001740
               PRINT EDGE0 V V00 KR YRS1;                                00001750
            STOP;                                                        00001760
         END;                                                            00001770
      * "CITYAOT" & "NCITYINF" ZEROED OUT BELOW "DO I";                  00001780
      NCINF=J.(DECADES,NR,0);                                            00001790
      PV=J.(2,YRS,0);                                                    00001800
      PDF=J.(DECADES,NS,0);                                              00001810
         *==HOLDS FV (FINALLY PV) OF CUM SIMS FOR VARIOUS LENGHT TIME;   00001820
      APHISPV=J.(DECADES,NS,0);  * PV OF APHIS COSTS;                    00001830
            *==# INFESTATIONS EA CITY THROUGH DECADES;                   00001840
      AREA=J.(2,YRS,0);                                                  00001850
         *== AREA ISO INFES OUTSIDE L EDGE AS FN OF GROWTH RATE;         00001860
      TOTACRES=J.(1,YRS,0);         *  AV EA YR OVER SIMULATIONS;        00001870
      ACRESNAT=J.(1,YRS,0);         *     NAT SPREAD SQ MI DURING SIM;   00001880
      YRLOSS=J.(3,YRS,0); *AV/SIM-BY YR FOR LIM, REC,RES,NOT DISC;       00001890
      APHISCOS=J.(4,YRS,0);* INSP, ERAD, SUM, TOT COSTS> BY YR PER SIM;  00001900
      INSPCOST=J.(1,YRS,0);     * YEARLY INSPECTION COSTS-SAVOME EA YR;  00001910
      SUMISO=J.(1,YRS,0); *    #   ISO INFEST EA YR, SAME FOR ;          00001920
                                                                         00001930
      IF ISOGROW=1 THEN DO; ISOGROW1; END; ****MACRO(3);                 00001940
                                                                         00001950
                   *  "NOINF1" GOES BELOW "DO I" IF DIFF EACH SIM(I);    00001960
      IF REGEFF ^=0 THEN NI=INT(NI*(1-REGEFF)+.5);                       00001970
      TNI=NI(,+);                                                        00001980
      SUMISO=NI(,1:YRS);                                                 00001990
      IF KOST=1 THEN DO; KOST1; END; ****MACRO(2);                       00002000
      TOTERAD=0;                                                         00002010
      NOTE DISCOUNT RATE (YEARLY RATE OF INTEREST);                      00002020
         PRINT R;                                                        00002030
         R=1+R;                                                          00002040
         CARRYFOR=R**10;                                                 00002050
      NOTE MACROS CHOOSEN FOR THIS COMPUTER RUN;                         00002060
         PRINT  ISOGROW KOST YRDATA;                                     00002070
      NOTE NO. OF SIMULATIONS IN THIS COMPUTER RUN;                      00002080
         PRINT NS;                                                       00002090
      NOTE NO. OF YEARS IN EACH SIMULATION;                              00002100
         PRINT YRS;                                                      00002110
      NOTE MAX NO. OF INDEPENDENT ISOLATED INFESTATIONS WITHIN A CITY    00002120
      NO ISOLATED INFESTATION ABOVE THIS NO. INCREASE DAMAGED AREA;      00002130
         PRINT NINFMAX;                                                  00002140
      NOTE PROPORTION OF CITY'S  AREA RECEIVING FULL RESIDENTIAL LOSS-FUNCTION00002150
       -- REMAINDER RECEIVES ONLY FRACTION OF PULL AMOUNT;               00002160
```

```
      PRINT PART;
   NOTE PROPORTION OF RESIDENTIAL LOSS FUNCTION CHARGED TO CITY AFTER SPECI
   FIED PROPORTION OF CITY''S AREA AFFECTED;
      PRINT FRACT;
   NOTE SCALE FACTOR FOR VALUES OF TIMBER, RECREATION & RESIDENTIAL LOSSES;
      PRINT ADJF;
   NOTE PROPORTION OF SMSA & GIA SAVED SUBJECT TO LOSSES FROM LUM,REC,RES;
      PRINT ADJEFF;
   NOTE LOSS FACTOR (PER SQ MILE) FOR ISO INFES IN SMSA'S & SECTOR OF AREA
   KEPT OUT OF GIA;
      PRINT LF;
   NOTE KEY FOR START OF RANDOM NO. GENERATOR;
      PRINT SFED;
   NOTE INITIAL "RADIUS" OF LEADING EDGE;
      PRINT EDGE0;
   NOTE NATURAL SPREAD RATE OF LEADING EDGE FOR SLOW & FAST AREAS  (MILES/Y
   EAR);
      PRINT V;
   NOTE BASE RUN NATURAL SPREAD RATE OF LEADING EDGE;
      PRINT V0;
   NOTE MIN DISTANCE FROM LEADING EDGE BEFORE ERADICATION EFFORTS WILL TAKE
    PLACE;
      PRINT BORDER;
   NOTE MIN DISTANCE FROM LEADING EDGE BEFORE DISTANCE AFFECTS THE PROBABIL
   ITY OF A RANDOM INFESTATION;
      PRINT KR;
   NOTE WIDTH OF "CORRIDOR" OF NAT SPREAD (SLOW & FAST) IN DEGREES;
      PRINT WIDTH;
   NOTE SLOW & FAST GROWTH RATES OF ISOLATED INFESTATIONS (1+GROWTH RATE);
      PRINT GR;
   NOTE AREA OF ISOLATED INFESTATION WHEN INITIALLY FOUND (ACRES);
      PRINT AREA0;
   NOTE AREA OF ISOLATED INFESTATION OVER TIME GIVEN INITIAL SIZE OF AREA &
    IT'S GROWTH RATE (SQ. MI.);
      PRINT AREA;
   NOTE COST OF SLOWING DOWN NATURAL SPREAD RATE GIVEN INITIAL LENGTH OF LE
   ADING EDGE;
      PRINT COSTNAT;
   NOTE FIXED COST OF APHIS INSPECTION PROGRAM;
      PRINT FC;
   NOTE VARIABLE COST OF APHIS PROGRAM;
      PRINT VC;
   NOTE COST OF ERADICATION OF A SINGLE ISOLATED INFESTATION---MUST BE "0"
    IF NO ERADICATION PROGRAM IS USED;
      PRINT ERADCOST;
   NOTE NO. OF YRS AFTER AN ISOLATED INFESTATION BEFORE IT BECOMES A MONETA
   RY FACTOR;
      PRINT SKIP;
```

```
NOTE PROPORTION OF NEW INFESTATIONS PREVENTED BY BETTER INSP;
   PRINT REGEFF;
NOTE TOTAL NUMBER OF ISOLATED INFESTATIONS IN EACH SIMULATION -- I.E.
 SUM OF ALL YEARS IN 'NI';
   PRINT TNI;
```

```
******************************* START OF SIMULATION **************;
DO I=1 TO NS;
   RADCOST=J.(1,YRS,0);
   NCITYINF=J.(DECADES,NR,0);
   CITYAOT=J.(NR,YRS,0);
   PV(1,)=YRLOSS(+,);
   EDGE=EDGE0;         * INITIALIZE LEADING EDGE;
   EDGE00=EDGE0;             * LE FOR BENCHMARD BASE RUN;
   DO J=1 TO YRS;
      NIERAD=0;
      EDGE=EDGE+ V;
      DO K=1 TO NI(1,J);
         RNUM=UNIFORM(SEED);
         MID=(CUMNUM(,J)<RNUM)(+,)+1;
                  * INERATE TABLE FOR # ISOLATED INF/CITY;
         DO L=1 TO DECADES;
            IF (J#/10)<= L THEN NCITYINF(L,MID)=NCITYINF(L,MID)+1;
         END;
         IF YRDATA=1 THEN DO; YRDATA1; END; ****MACRO(4);
      END;
      TOTERAD=TOTERAD+NIERAD;
      RADCOST(1,J)=NIERAD*ERADCOST+RADCOST(1,J);
   IF V^=V0 THEN DO;  * 'DC' WORKS ONLY IF CONSTANT VALUE FOR REC,RES;
      EDGE00=EDGE00+V0;
      SAVEAREA=-(WIDTH#(EDGE+EDGE00)#(EDGE-EDGE00))(+,)*3.14159#/360;
      DO K=1 TO 3;
         IF ADJEFF(2,K)^=0 THEN
         YRLOSS(K,J)=YRLOSS(K,J)-SAVEAREA*LF(2,K);
      END;
   END;
   END;
   NCINF=NCINF+NCITYINF;   * CUM # INF EA CITY, DECADE ALL SIMS;
               * GET FUTURE VALUES;
APHISCOS(1,)=APHISCOS(1,)+INSPCOST;
APHISCOS(2,)=APHISCOS(2,)+RADCOST;
PV(1,)=YRLOSS(+,)-PV(1,);     * INITIAL YEAR'S VALUES;
PV(2,)=INSPCOST+RADCOST;
YRAMT=PV(,1);
DO L=2 TO YRS;                   * CARRY OUT TO FUTURE VALUES;
```

```
      YRAMT=YRAMT*R+PV(,L);
      IF (MOD(L,10)=0) THEN DO;   * SAVE DECADE VALUE(S) THIS SIM;
         LL=L#/10;
         PDF(LL,I)=YRAMT(1,1);
         APHISPV(LL,I)=YRAMT(2,1);
      END;
   END;
   END;
   *******************************END OF SIMULATION**********;
```

```
                     * DISCCUNT ALL SIMS TO PV;
DF1=INV(CARRYFOR);
DF=DF1;
DO L=1 TO DECADES;
   PDF(L,)=PDF(L,)*DF;
   APHISPV(L,)=APHISPV(L,)*DF;
   DF=DF*DF1;
END;
TPDF=APHISPV+PDF;
                                   * AVERAGES OVER SIMS;
IF (NS>1) THEN DO;
   APHISCOS(1,)=APHISCOS(1,)#/NS;
   APHISCOS(2,)=APHISCOS(2,)#/NS;
   NCINF=NCINF#/NS;
   TOTACRES=TOTACRES#/NS;
   TOTERAD=TOTERAD#/NS;
   YRLOSS=YRLOSS#/NS;
END;
APHISCOS(3,)=APHISCOS(1,)+APHISCOS(2,);
APHISCOS(4,)=APHISCOS(3,)+YRLOSS(+,);
YRLOSS=YRLOSS#/1000;   * CONVERT TO THOUSAND DOLLARS;
APHISCOS=APHISCOS#/1000;   *CONVERT TO THOUSAND DOLLARS;
INVR1=INV(R);
INVR=INVR1;
A=YRLOSS//APHISCOS;
A(,1)=A(,1)*INVR;
DO L=2 TO YRS;      * PRESENT VALUE THROUGH YEAR(L);
   INVR=INVR*INVR1;
   A(,L)=A(,L-1)+A(,L)*INVR;
END;
                     * OUTPUT MATRICES TO SASDS;
A=(SUMISO//TOTACRES//ACRESNAT//A)';
OUTPUT A OUT=ANS4;
      A=(SUMISO//TOTACRES//ACRESNAT//YRLOSS//APHISCOS)  ';
      OUTPUT A OUT=    ANS1;
      A=PDF';
      OUTPUT A OUT=    ANS2;
      A=NCINF';
*A;   OUTPUT A OUT=    ANS3 (RENAME=(COL1= DECADE_1
```

```
348            COL2=DECADE_2 COL3=DECADE_3));                             00003590
349        NOTE TOTAL AV. NUMBER OF ISOLATED INFESTATIONS ERADICATED BY APHIS/SIM; 00003600
350           PRINT TOTERAD;                                               00003610
351        NOTE 'PRESENT VALUE OF LOSSES -- ALL SIMULATIONS & DECADES -- (COL      00003620
352        SIMULATIONS,  ROWS=DECADES)';                                  00003630
353           PRINT PDF;                                                   00003640
354        NOTE 'PRESENT VALUE APHIS COSTS --';                           00003650
355           PRINT APHISPV;                                               00003660
356        NOTE 'PRESENT VALUE SUM OF LOSSES & APHIS COSTS --';           00003670
357           PRINT TPDF;                                                  00003680

NOTE: DATA SET WORK.ANS4 HAS 30 OBSERVATIONS AND 11 VARIABLES. 207 OBS/TRK.
NOTE: DATA SET WORK.ANS1 HAS 30 OBSERVATIONS AND 11 VARIABLES. 207 OBS/TRK.
NOTE: DATA SET WORK.ANS2 HAS 1 OBSERVATIONS AND 4 VARIABLES. 529 OBS/TRK.
NOTE: DATA SET WORK.ANS3 HAS 217 OBSERVATIONS AND 4 VARIABLES. 529 OBS/TRK.
NOTE: THE PROCEDURE MATRIX USED 17.35 SECONDS AND 324K AND PRINTED PAGES 1 TO 6.

358        DATA _NULL_;                                                    00003690
359           SET ANS1;                                                    00003700
360           N=SUM(N,1);                                                  00003710
361           RETAIN N 1980;                                               00003720
362           FILE PRINT HEADER=H NOTITLES;                                00003730
363           PUT @11 N 5. @21 COL1 5.   @27 COL2 11.                      00003740
364               @39 COL3 11.   @51 COL4 DOLLAR10.                        00003750
365               @63 COL5 DOLLAR10.  @77 COL6 DOLLAR10.                   00003760
366               @88 COL7 DOLLAR8.   @98 COL8 DOLLAR8.                    00003770
367               @107 COL9 DOLLAR9.  @117 COL10 DOLLAR10.;                00003780
368           RETURN;                                                      00003790
369           H: PUT / @51 'STATS FOR GM SIMULATION ' // @26               00003800
370                 'AV. OVER ALL SIMULATIONS, VALUE IN THOUSANDS OF DOLLARS, '  00003810
371                 'FOR YEAR, NOT DISCOUNTED'/;                           00003820
372        PUT @ 45 'TOTAL';                                               00003830
373           PUT @21 'TOTAL' @34 'AREA' @42 'ADD AREA' @56 'VALUE' @68 'VALUE'     00003840
374               @82 'VALUE' @91 'APHIS' @101 'APHIS' @111 'APHIS' @122 'COSTS';  00003850
375           PUT @23 'NEW' @32 'OF ISO' @41 'GENERALLY' @59 'OF' @71 'OF' @85 'OF'00003860
376               @91 'INSP' @102 'ERAD' @111 'TOTAL' @123 'PLUS';         00003870
377           PUT @14 'YR' @21 'INFES' @33 'INFES' @42 'INFESTED' @55 'TIMBER'     00003880
378               @63 'RECREATION' @76 'RESIDENTIAL' @91 'COSTS'@101 'COSTS'       00003890
379               @111 'COSTS' @121  'LOSSES';                             00003900
380           PUT @14 'NO' @21 'EA YR' @31 '(SQ MI)' @43 '(SQ MI)' @55 'LOSSES'    00003910
381               @67 'LOSSES' @81 'LOSSES'/;                              00003920
382           RETURN;                                                      00003930

NOTE: 38 LINES WERE WRITTEN TO FILE PRINT.
NOTE: THE DATA STATEMENT USED 0.16 SECONDS AND 180K.

383        DATA _NULL_;                                                    00003940
384           SET ANS4;                                                    00003950
```

```
385          N=SUM(N,1);                                                       00003960
386          RETAIN N 1980;                                                    00003970
387          FILE PRINT HEADER=HH NOTITLES;                                    00003980
388          PUT @11 N 5. @21 COL1 5.   @27 COL2 11.                           00003990
389              @39 COL3 11.   @51 COL4 DOLLAR10.                             00004000
390              @63 COL5 DOLLAR10.  @77 COL6 DOLLAR10.                        00004010
391              @88 COL7 DOLLAR8.   @98 COL8 DOLLAR8.                         00004020
392              @107 COL9 DOLLAR9.  @117 COL10 DOLLAR10.;                     00004030
393          RETURN;                                                           00004040
394          HH: PUT / @51 'STATS FOR GM SIMULATION ' // @26                   00004050
395                  'AV. OVER ALL SIMULATIONS, VALUE IN THOUSANDS OF DOLLARS, ' 00004060
396                  'DISCOUNTED TO PRESENT VALUE'/;                           00004070
397        PUT @ 45 'TOTAL';                                                   00004080
398          PUT @21 'TOTAL' @34 'AREA' @42 'ADD AREA' @56 'VALUE' @68 'VALUE'  00004090
399              @82 'VALUE' @91 'APHIS' @101 'APHIS' @111 'APHIS' @122 'COSTS'; 00004100
400          PUT @23 'NEW' @32 'OF ISO' @41 'GENERALLY' @59 'OF' @71 'OF' @85 'OF'00004110
401              @91 'INSP' @102 'ERAD' @111 'TOTAL' @123 'PLUS';              00004120
402          PUT @14 'YR' @21 'INFES' @33 'INFES' @42 'INFESTED' @55 'TIMBER'  00004130
403              @63 'RECREATION' @76 'RESIDENTIAL' @91 'COSTS'@101 'COSTS'    00004140
404              @111 'COSTS' @121  'LOSSES';                                  00004150
405          PUT @14 'NO' @21 'EA YR' @31 '(SQ MI)' @43 '(SQ MI)' @55 'LOSSES' 00004160
406              @67 'LOSSES' @81 'LCSSES'/;                                   00004170
407          RETURN;                                                           00004180

NOTE: 38 LINES WERE WRITTEN TO FILE PRINT.
NOTE: THE DATA STATEMENT USED 0.15 SECONDS AND 180K.

408        DATA NEW(DROP=ROW E);                                               00004190
409           MERGE ANS3 SIM;                                                  00004200

NOTE: DATA SET WORK.NEW HAS 217 OBSERVATIONS AND 13 VARIABLES. 174 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.13 SECONDS AND 180K.

410        DATA NEW1;                                                          00004210
411           SET NEW;                                                         00004220
412           N+1;                                                             00004230

NOTE: DATA SET WORK.NEW1 HAS 217 OBSERVATIONS AND 14 VARIABLES. 162 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.11 SECONDS AND 180K.

413        PROC PRINT DATA=NEW1;                                               00004240
414           DROP  DUMMY VR;                                                  00004250
415           ID N CITY STATE;                                                 00004260
416           TITLE AV. TOTAL NO. OF ISO. INFES. FOR EACH CITY FROM TIME=0 THROUGH 00004270
417         END OF DECADE(I)==DECADE_I;                                        00004280

NOTE: THE PROCEDURE PRINT USED 0.43 SECONDS AND 172K AND PRINTED PAGES 7 TO 11.
```